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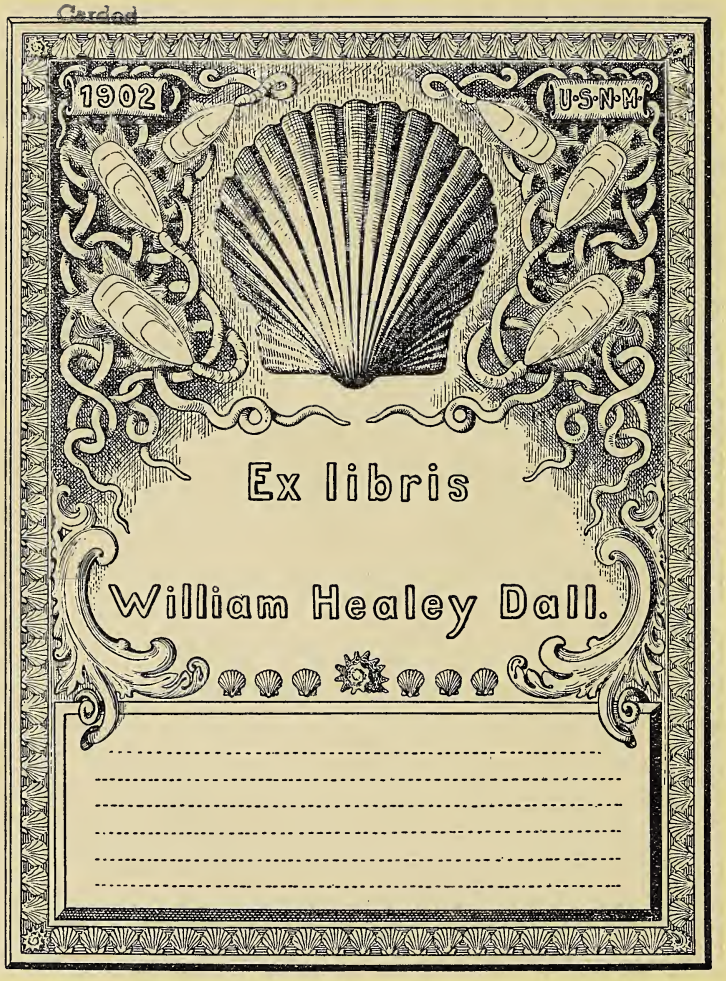

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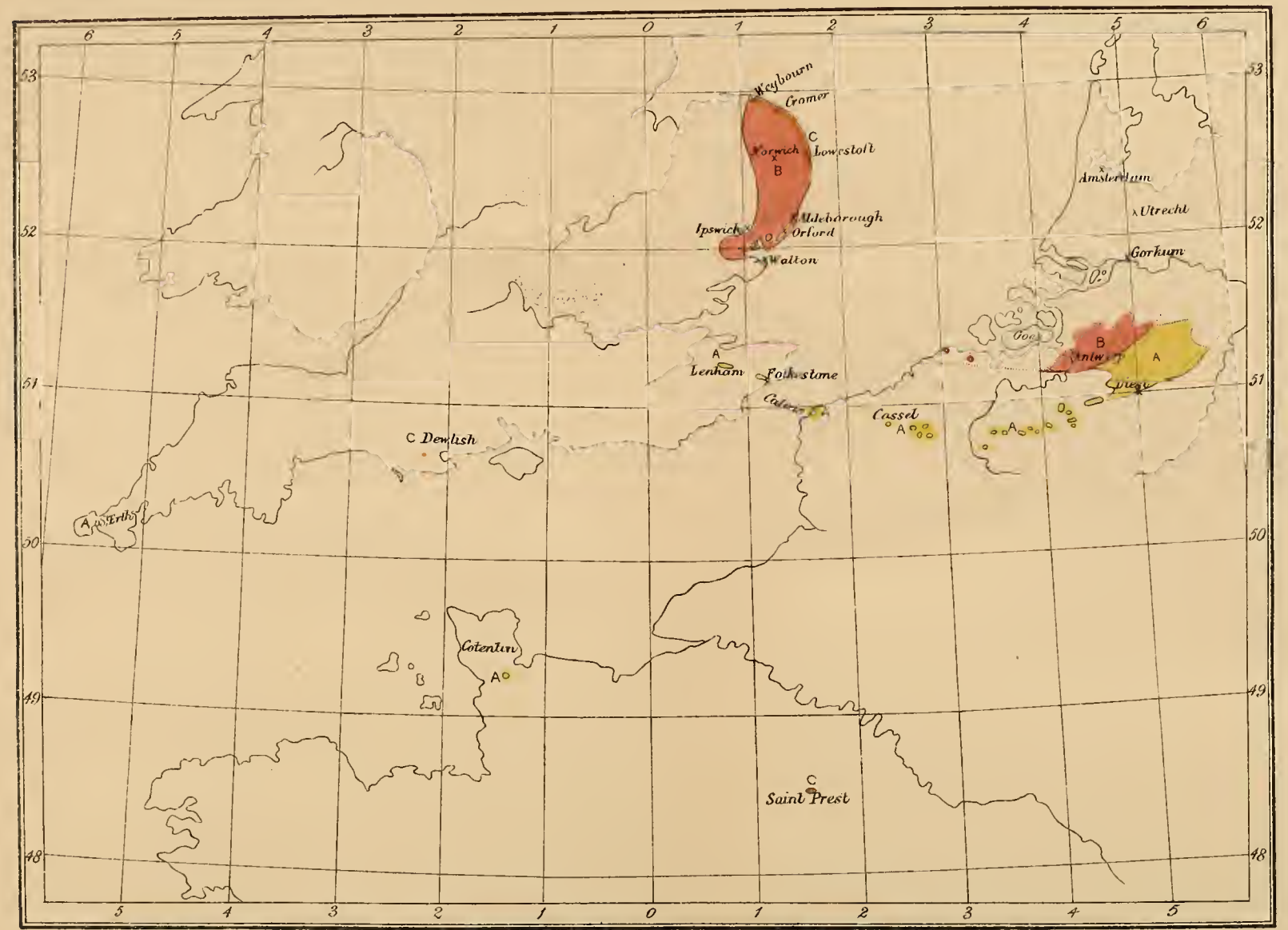
Map Showing the Distribution of the Pliocene Strata in Northern Europe.



A Older Pliocene (marine)

B Newer Pliocene (marine)

C Newer Pliocene (freshwater & estuarine)

Pliocene deposits also underlie the Alluvium of Holland but the limits are still unknown.

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MAP SHOWING THE DISTRIBUTION OF THE PLIO

A — Older Pliocene (marine)

B — Newer Pliocene (marine)

Pliocene deposits also underlie the Alluvium of Holla

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W. H. Dall, Esqre
with the author's compliments

MEMOIRS OF THE GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM.

THE

PLIOCENE DEPOSITS

OF

BRITAIN.

Division of Mollusks
Sectional Library

BY

CLEMENT REID, F.L.S., F.G.S.

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E

PREFACE.

The Geological Survey Map of England and Wales having been completed, it has now become possible to collate the work done by the Survey and by other observers in the different geological formations of the kingdom, and to prepare the general stratigraphical memoirs, to which the local or sheet-memoirs hitherto published were intended to be introductory. These general memoirs are designed to present a compendium of all that is known regarding each of the geological formations in its distribution through the United Kingdom. They will thus include the condensed results of the labours of the Geological Survey, with full reference to the maps and sheet-memoirs where local details have already been given. It will be impossible to follow the strict stratigraphical sequence in their publication. They will be issued in the order in which they can be most speedily prepared.

The present work is the first of these stratigraphical memoirs. It has been written by Mr. Clement Reid, and is designed not only to bring together the results of the work of the Geological Survey among the Pliocene deposits, but to present a faithful summary of the present state of knowledge regarding that portion of the Geological Record in this country. In pursuance of this design full use has been made of the maps, memoirs, and unpublished work which the Survey has accumulated during the progress of the mapping in the eastern counties. Among the members of the Survey whose labours have been of special service in the preparation of this volume reference may be made to Messrs. Whitaker, Woodward, Dalton, Blake, and E. T. Newton. Fuller acknowledgment of the work of these observers, and of others outside of the Survey, will be found in the text.

While ths work was in preparation Mr. Reid, who had himself mapped considerable tracts of newer Pliocene deposits in Norfolk, made a careful examination of the disputed Lenham deposits, collected a considerable number of shells from them, and I think finally settled their relative geological age—a question of great importance, not only in regard to the general Pliocene succession in England, but also of singular interest in regard to the later Tertiary and post-Tertiary terrestrial movements in western Europe. He also studied the deposits at St. Erth, St. Agnes Beacon, and Dewlish.

It appeared to me eminently desirable that, besides examining the English Pliocene strata, the author of this work should have an opportunity of comparing them with some of their best known and most important Continental equivalents. He was accordingly sent to make a series of observations in Belgium, France, and Italy, and the results of these journeys are embodied in the following chapters. Having thus gained an enlarged experience among the younger Tertiary deposits of western and southern Europe,

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Mr. Reid has been able to enter more fully into such questions as the physical conditions under which the Pliocene strata were deposited, the climate and the natural history of the seas of later Tertiary time, the terrestrial movements of Pliocene date and their relation to the topography of the south of England and to the existing physical geography of north-western Europe.

In any work treating of the Pliocene deposits of Britain a foremost place of recognition must be given to the names of Charlesworth, who proposed the divisions now adopted; Lyell, who classified the whole Tertiary series; Prestwich, who did such eminent service in the Crag district and at Lenham; S. V. Wood, whose "Crag Mollusca" is one of the classics of Geology; and Messrs. Wood, Junior, and Harmer, who made the first detailed map of the Pliocene deposits of the eastern counties. Of the labours of these and other observers large use has been made in the following chapters, as the references in the text will show.

I have to express my thanks to Professor Prestwich and to the Council of the Geological Society for permission to use the woodcuts from the "Quarterly Journal" of that Society; also to many foreign geologists for the assistance they have so freely rendered to Mr. Reid in his researches, especially to M. E. Van den Broeck, and to M. Cogels, and Baron Van Ertborn in Belgium; to Professor De Stefani, Dr. Ristori, Dr. Canavari, Professor Capellini, Professor Meli, Professor Sacco, and the late Professor Meneghini in Italy; to M. G. Dolfuss and M. Maurice Vignier in France; and to Dr. J. Lorié of Utrecht. Many of these geologists, besides communicating valuable information or facilitating a study of the specimens in the museums under their charge, accompanied Mr. Reid into the field and thus enabled him to obtain full and accurate information regarding the sections which he visited.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, Jermyn Street, London.
4th June 1890.

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THE

PLIOCENE DEPOSITS

OF

BRITAIN.

CHAPTER I.

INTRODUCTION.

During the past sixty years the study of the deposits, once vaguely spoken of as "Supra-Cretaceous" or "Tertiary," has led to a more and more exact classification. But though a great advance has been made, it is still necessary to define the sense in which the term Pliocene is used in the following pages, for custom has not yet fixed the limits of the period which it denotes.

It is needless for this purpose to go back further than the first edition of Lyell's "Principles of Geology," for in the third volume of that work, published in 1833, the Tertiary rocks were for the first time divided into groups approximating to those now in use. Lyell subdivided the Tertiary strata into three series, according to the relative proportion of living and extinct mollusca found in them, and named them Eocene, Miocene, and Pliocene. Subsequently the Eocene series was divided into two, and the upper part named Oligocene; and the original Newer Pliocene group of Lyell was raised to the rank of a distinct formation, under the name of Pleistocene.

The Pliocene, which is the only formation dealt with in this Memoir, was defined by Lyell as including all strata which contain from 36 to 95 per cent. of recent marine mollusca. This test, though readily applied, is somewhat arbitrary; for the percentages in strata really contemporaneous may vary considerably from local causes. We must regard the percentage test, like the Linnean system in botany, not as fixing a rigid standard by which all questions must be decided, but as avaluable key, to be used temporarily until a more natural system becomes available.

Lyell himself does not appear ever to have regarded it as anything more than this.

There is, however, no difficulty in fixing the lower limit of the Pliocene system in England, for unfortunately no deposits of Miocene age are yet known here, and we commence with strata yielding over 50 per cent. of recent mollusca. The higher limit cannot well be settled by the percentage test, for we have too small a number of marine mollusca from the highest Pliocene and lowest Pleistocene deposits to allow of comparison. The effects of the marked change of climate that occurred after the Cromer Forest-bed was deposited seem, however, to form a natural close to the period, for the refrigeration apparently caused the extinction of a large proportion of the higher animals, though the invertebrates and plants lived on.

Thus under the term Pliocene we may include all strata deposited after the sub-tropical Miocene period, and before the incoming of the intense cold of the earliest Pleistocene ages. A change from warm temperate to cold temperate occurred in Britain during the Pliocene period. There may have been minor oscillations; but the change from conditions like those now existing in the Mediterranean region, to a climate like that now found in England, seems to have been fairly continuous and regular. The alternation in the uppermost Crag of a boreal marine fauna with land-animals and plants of the temperate zone, is probably due, as we shall show, to local causes, for the temperate land fauna and the arctic marine fauna occur also mixed in the same estuarine deposits.

In Britain this change of climate during the period may be used even further in the classification, for our Pliocene strata fall naturally into two groups—those of the warm temperate and those of the cold temperate period—with a break and distinct unconformity between them. The division of the newer Pliocene deposits into a lower marine and an upper freshwater and estuarine series completes the main outlines of the classification, though several minor zones can be recognized. The following are the subdivisions adopted in this Memoir:—

- Base of the Pleistocene.
  - Arctic Freshwater Bed (with *Salix polaris*, *Betula nana*, &c.
- Newer Pliocene (cold temperate).
  - *Leda-myalis* Bed (classed provisionally with the Pliocene).
  - Forest-bed Series.
    - Upper Freshwater
    - Estuarine
    - Lower Freshwater

    } Gravels with Elephas meridionalis at Dewlish.
  - Weybourn Crag (and Chillesford Clay?).
  - Chillesford Crag.
  - Norwich Crag and *Scrobicularia* Crag.
  - Red Crag of Butley, &c.
  - Walton Crag (lower Red Crag).
- Older Pliocene (warm temperate).
  - St. Erth Beds.
  - Coralline Crag.
  - Lenham Beds.
  - Box stones and phosphate beds (with *remanié* early Pliocene fossils).

"Crag" is a local term commonly applied in the east of England to any shelly marine sand. The word has been adopted by geologists as almost equivalent to "Pliocene," but it is never used for clays, such as the Chillesford Clay or Forest-bed.

There is a great gap in Britain between the Pliocene strata and the next deposit below; for the Hamstead Beds (Middle Oligocene) yield a fauna of a totally different character, having few, if any, of the species found in the strata above. The lapse of time denoted by this gap was so great that enormous masses of sediment were laid down in other districts during the interval. In Britain, though the intervening strata are absent, yet the great flexures in the south of England, and the thorough discordance between the Pliocene rocks and the underlying strata, serve to indicate how important the break really is. The movements in the south of England tilted the Oligocene deposits till they were vertical; but the oldest Pliocene strata seem to have been laid down when this folding had nearly ceased, and after denudation had removed the lower Tertiary groups. We thus find at Lenham Older Pliocene strata resting directly on the Chalk, and little, if at all, affected by the proximity of the Wealden anticline.

The geographical distribution of our Pliocene deposits will best be understood by a reference to the Map at the commencement of this volume. Those of Older Pliocene age occupy a small area, being almost confined to the district around Orford, in Suffolk. Here the Coralline Crag occupies about 10 square miles. There are also small outliers at Ramsholt and Sutton, and a third, more distant, at Tattingstone, between Ipswich and Manningtree. All these localities are in the south-eastern part of the county of Suffolk. South of the Thames a small outlier of fossiliferous Lower Pliocene sands occurs on the edge of the North Downs, at Lenham, 10 miles east of Maidstone, and ironstones, probably of the same age, here and there cap the highest portion of the Down as far as Folkestone. One other small patch of Older Pliocene strata is found near the village of St. Erth, between St. Ives and Marazion, in Cornwall. There are also some curious sands at St. Agnes Beacon, on the north coast of Cornwall, which are probably of the same age, though they have as yet yielded no fossils.

Taking the whole of the fossiliferous Lower Pliocene deposits in Britain, and allowing for their probable extension under later formations in Suffolk, the total area occupied by them does not exceed 15 square miles. Even if we take into account all the deposits that can with any show of probability be referred to this period, such as the ironstone at Folkestone and the sands at St. Agnes Beacon, the area will not exceed 20 square miles. It is essential, however, to distinguish between the present limits of a formation and its original extension. The marine Older Pliocene strata evidently once extended far and wide over Britain, though they have now been reduced by denudation to such small and widely separated outliers.

The marine Newer Pliocene deposits were in all probability of much smaller extent than the older series originally, but denudation has affected them less. The area occupied by the Red, Norwich, Chillesford, and Weybourn Crags is now considerably greater than that of the older series, though on the other hand, its present western limit is probably not far from the original shore-line. The upper Crag occupies the eastern half of Norfolk and Suffolk, and extends a short distance into Essex. It seems formerly to have stretched as far south as the Blackwater. Leaving out of account the small gaps caused by recent and glacial denudation, the total area over which the upper Crag can be traced amounts to about 1,200 square miles. We must also not forget that this is only the western margin of a deposit which dips beneath the North Sea, and perhaps stretches continuously to Belgium and Holland, where it re-appears as the Scaldisian or Upper Crag.

No deposits of this age are known in any other part of Britain, though the occurrence of derivative Crag shells in the Drift of Aberdeenshire seems to show that beds like the Red Crag must occur beneath the North Sea somewhere in that neighbourhood.

The next division, the sub-aërial, freshwater, and estuarine deposits, known as the Cromer Forest-bed, occupies only a limited area. It extends along the Norfolk and Suffolk coast for about 45 miles, but its inland boundary cannot be fixed, owing to the great thickness of the overlying Drift, and for some distance on each side of Yarmouth it is also invisible, though probably occurring beneath the sea-level. There is a small outlier of mammaliferous gravel containing a similar fauna, at Dewlish in Dorsetshire. Otherwise nothing that can be referred to this subdivision of the Pliocene series is known beyond the limits of east Norfolk and east Suffolk. Capping hills in various parts of the east and south of England there are, however, outliers of gravel which, from their peculiar character and position, seem to date from before the Glacial Epoch. These will be described in Chapter X., but as they are all unfossiliferous, and perhaps of very different ages, their distribution has not been marked on the map at the beginning of this volume.

It will be observed that reference is constantly made in the following pages to the foreign equivalents of the different strata under discussion. This is done, not with the object of referring our Pliocene strata to divisions established beyond the limits of this country, or to arbitrarily selected "types," but to prevent the thin series in England from being taken as in any way forming a stratigraphical and palæontological standard. It so happens that England has by far the most complete series of Pliocene deposits of any part of Northern Europe, and the strata here are more generally fossiliferous. In the Mediterranean region, however, the series is much more complete, especially in Italy. We find the period represented there by so enormous a mass of deposits, that our ideas of its importance are greatly altered. We also

discover that the minor subdivisions made in northern Europe are quite inapplicable in the south, and that at present scarcely sufficient evidence exists to decide their exact equivalents in time. The table of foreign equivalents (pp. 222, 223) for this reason is purposely confined to the broad outlines. No doubt the deposits have been correlated more minutely, and fuller tables will be found in many memoirs and geological manuals, but the closer one studies the records of the Pliocene period, the more hazardous seems any attempt at correlation of the subordinate zones in districts 700 miles apart, divided by 10° of latitude, and separated by areas of which the Pliocene history is almost a blank.

CHAPTER II.

THE NODULE BEDS, OR BASEMENT BEDS OF THE CRAG.

In Britain, as already pointed out, there is a wide gap between the Lower and the Upper Tertiary strata, marked by the disappearance of nearly all the sub-tropical animals and plants of the Oligocene period and the incoming of a quite new set, no longer sub-tropical though still showing a climate considerably warmer than that now found in these latitudes. The break in the eastern counties is particularly well marked, for there our oldest Pliocene deposits rest directly on the London Clay, and the only indication of the former existence of anything of intermediate date is found in the phosphate beds, or "coprolite beds," as they are often wrongly called, which occur at the base both of the Coralline and Red Crags.

The "Nodule Bed" seems to be nearly co-extensive with the Red Crag, and probably also with the Coralline Crag, though often too thin to be of any economic importance. It has been extensively worked for phosphatic nodules and phosphatised bones, and a large amount of information has been obtained as to the origin of the deposits and the character of the included fauna. A large proportion of the fossils appears to belong to a period somewhat earlier than the Crag, though still truly Pliocene, and for this reason, and on account of its peculiar lithological character, the Nodule Bed, though really nothing but the basement bed of the overlying Crag, is here described as a separate stratum.

Most of the papers noticing the Nodule Bed treat it merely as part of the overlying Crag, but a few that deal more especially with the origin of the nodules and the age of their fossils must be mentioned here—the others will be referred to in the chapters on the Coralline and Red Crags.

The first mention of the nodules appears to have been in 1844, when Prof. Henslow* described the concretions from the Red Crag at Felixstow. He came to the conclusion that they were of coprolitic origin. He also noticed the occurrence among the nodules of the petro-tympanic bones of at least four species of Cetaceans (described in an Appendix by Sir R. Owen†).

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* *Proc. Geol. Soc.*, vol. iv. pp. 281–283. Reprinted in *Quart. Journ. Geol. Soc.*, vol. i. pp. 35–37. (1845.)

† *Ibid.*, pp. 283–286.

In 1845 Prof. Henslow* again noticed the occurrence of phosphatic nodules in the Crag, and quoted Mr. Brown of Stanway as having analysed them and found the same amount of phosphate of lime as in similar nodules from the London Clay. This resemblance of composition, and the occurrence of small crabs and fish like those in the London Clay, led Mr. Brown to the conclusion that the pebbles in the Crag were derived from that series. Prof. Henslow also spoke of an attempt having been made to test the economic value of the deposit.

In 1846 Sir R. Owen† described the Mammalian fossils of the Red Crag, and concluded that the Cetacean ear-bones and teeth had been derived from Eocene beds, from the mistaken idea that a Cetotolite had been found in the London Clay, it being recorded as "from Harwich Cliff."

Prof. Henslow, recurring to the subject of his paper of 1845, two years later,‡ thought that various bones had been derived from the London Clay, as true Crag fossils in his opinion differed from these older fossils in not being mineralized. He stated that the Cetacean remains described by Sir R. Owen must be classed with the detrital materials from the London Clay.

In 1849§ Buckland said that none of the phosphatic nodules from the Crag were true coprolites. He also spoke of the conditions under which the phosphatic deposits might have been formed in the London Clay from the decomposition of organic matter, but suggested also that many of the nodules in the Crag might have absorbed a larger amount of phosphorus since they were washed out of their matrix in the London Clay.

In 1851 Dr. W. B. Clarke,‖ of Ipswich, gave a further account of the Nodule Bed and its contents, and T. J. Herapath¶ published a valuable series of analyses of the fossil bones and of the phosphatic nodules, though subsequent analyses by other chemists show that the *average* amount of phosphates is somewhat less and the silica much greater. In 1854 a suggestion was made by Prof. Johnston** that the phosphorus of the phosphatic nodules was derived from animal remains in higher beds, dissolved out by acids, and re-deposited at a lower level.

S. V. Wood in 1859 drew attention to the extraneous fossils of the Red Crag,†† and remarked that this deposit shows the action of strong tidal currents, is more littoral in character, and contains a larger per-centage of derived fossils than any other formation. He suggested that Christchurch Bay (Hampshire) shows like conditions to those of the Red Crag sea. He regarded the terrestrial vertebrates as intruders, but differed from Sir R.

---

* *Rep. Brit. Assoc.* for 1845, *Sections*, pp. 51–52. (1846.)
† A History of British Fossil Mammals and Birds. 8vo. *London.* p. 542.
‡ *Rep. Brit. Assoc.* for 1847, *Sections*, p. 64. (1848.)
§ *Journ. R. Agric. Soc.*, vol. x. pp. 520–525.
‖ *Ann. Nat. Hist.*, ser. 2, vol. viii. pp, 205–211.
¶ *Journ. R. Agric. Soc.*, vol. xii. pp. 91–105.
** *Rep. Brit. Assoc.* for 1853, *Sections*, p. 52.
†† *Quart. Journ. Geol. Soc.*, vol. xv. pp. 32–45.

Owen as to the Cetotolites having been derived from the London Clay, thinking that they more probably came from the Coralline Crag, or some other deposit of newer Tertiary age. Most of the fish-teeth might, in his opinion, have come from the London Clay, as well as some shells and many crustacea; there being few Secondary fossils. He believed, therefore, that the Red Crag sea was chiefly bounded by London Clay land, the fossils from which were introduced into the Crag by coast-action. The sandstone nodules, mixed with the phosphatic nodules, some of which contain casts of shells, he regarded as of older Crag age, though there is no similar material in our existing Coralline Crag. The Red Crag might thus include the harder fragments of various Tertiary beds. This paper concludes with a list of the derived fossils.

In 1865 Prof. E. R. Lankester* treated of the sources of the mammalian fossils. He considered that the derivative fossils can be distinguished by their greater density and mineralization, that in the Nodule Bed not one fauna, but a mixture or selection from several, belonging to Pliocene, Miocene, and Eocene strata may be recognised; that the Cetacean bones were derived from some deposit of the age of the Middle Crag of Antwerp, which contains similar species in an unworn state; and that certain of the land mammals come from a Miocene bed; while *Hyracotherium*, *Coryphodon*, and many of the sharks point to Eocene strata.

The same author in 1867,† referring to the suggested correlation of the Coralline Crag with the Black Crag of Belgium, asked, if this be the case, how the occurrence of the *remanié* teeth of similar sharks and Cetacea in *both* of our Crags to be accounted for, since no unworn specimens occur in our Coralline Crag, as they do in the Black Crag, whence, he asked, came the abundant derivative Cetacean and shark fauna of our Red Crag. He reiterated his conclusion that the Black Crag is an older deposit of the Crag sea, which had its representative in Suffolk, and from which first the Coralline and then the Red Crag derived their sharks' teeth and Cetacean bones.

In 1868 Prof. Lankester‡, reverting to his published opinions, especially as to the derivation of the bones of the "coprolite-bed" from Diestian deposits, noted the finding of 30 or more species of molluscs in the sandstone-blocks (box-stones) which seem to be Diestian, and of the largest *Carcharodon* tooth he had seen. He regarded the "coprolite-bed" as a littoral accumulation, formed, just before the Coralline Crag, from the detritus of London Clay and Diestian strata, with fragments of subaërial and freshwater accumulations (whence its *Mastodon*, *Rhinoceros*, *Tapir*, *Hyæna*, *Sus*, and *Cervus* teeth). He objected to the name "coprolite-bed," because there is probably not one coprolite in it, the nodules being masses of London Clay which

* *Quart. Journ. Geol. Soc.*, vol. xxi. pp. 221–226.
† *Geol. Mag.*, vol. iv. pp. 91–92.
‡ *Ibid.*, vol. v. pp. 254–258.

have received some 50 per cent. of phosphate of lime from the quantities of bones with which they were associated on the sea-shore He explained the rarity of bones of terrestrial Mammals, as compared with those of Cetaceans, from the fact that the former came on to the beach in a different state of preservation to the latter, which were derived from Diestian beds. The fresher bones would be more easily acted on by the sea than those already mineralised.

Mr. E. Charlesworth,* later in the same year, noticed that the phosphatic matter often encloses the fangs of the sharks' teeth, the tooth proper being left free, and that it is only such teeth as have been derived from the London Clay that are thus included in phosphate, whence he concluded that all the phosphatic stone (as distinguished from bones) in the Crag had been derived from the London Clay.

In 1870 Prof. Lankester† treated of the composition of the Nodule Bed at length, and described and figured some of its more remarkable fossils. He also pointed out that the Nodule Bed occurs beneath the Coralline Crag as well as beneath the Red Crag. He gave a detailed account of the sandstone nodules that occur in the bone-bed, which he calls box-stones, though the majority contain no fossils; the name boxes has been given by the phosphate-diggers to those that show hollow moulds of shells on being broken. After examining a large number he concluded that all have been derived from one deposit, of Diestian age; and that they are probably coeval with the Lenham sandstone of Kent. They represent a period separated by a wide gap from the Red and Coralline Crags. Lists of the fossils found in these stones, and of the Mammalia from the bone-bed are given.

In 1871 Prof. Prestwich‡ gave further particulars of the Nodule Bed, and described the section at Sutton, where the phosphatic nodules are found beneath the Coralline Crag.

Subsequently Messrs. Whitaker and Dalton gave details of all the sections in the Memoirs of the Geological Survey relating to the Red Crag district. Those referring to the Nodule Bed are the ones on the "Eastern end of Essex (Walton Naze and Harwich)" 1877, on "Ipswich, Hadleigh, and Felixstow" 1885, and on "Aldborough, Framlingham, Orford, and Woodbridge" 1886.

But for the economic value of the Nodule Bed, and the extensive scale on which it has been worked, we should know little about the interesting derivative fauna contained in it. This bed is one of the same kind as those at the base of the Chalk, and in the Lower Greensand, in Cambridgeshire, Bedfordshire, etc., all of them being of a conglomeratic or gravelly character, and containing so-called "coprolites," or fossils and nodules composed chiefly of phosphate of lime.

* *Geol. Mag.*, vol. v. pp. 577–580.
† *Quart. Journ. Geol. Soc.*, vol. xxvi. pp. 493–514.
‡ *Ibid.*, vol. xxvii. pp. 116–118, 326, 327, 341, 347–349.

The Nodule Bed of the Crag contains the usual shells of the Red or Coralline Crag, together with a miscellaneous collection of various rocks, in small waterworn pieces and in larger blocks. Amongst these Chalk-flints and flint-pebbles are the most plentiful, many of the former being unworn and partly covered with the shells of a *Balanus;* quartz and quartzite also occur, and pieces of sandstone (Carboniferous and Greywether), of various Jurassic and Cretaceous beds, of granite and other igneous rocks, and of London Clay septaria (sometimes large). The most peculiar of the rock-contents are, however, the "box-stones," above referred to. These are irregular rounded lumps of a tough, brownish sandstone, shown, by the contained fossils, to be of comparatively late Tertiary age, though older than the Coralline Crag, and lithologically unlike any members of the English Tertiary formations.

Besides the phosphatic nodules, great numbers of phosphatized fossils occur, which, like the rocks, are of various ages. Among them are numerous fragments of Jurassic Ammonites, imbedded in a matrix similar to that containing the London Clay species. Like most of the Eocene nodules they are probably altered fragments of septaria, or clay-pebbles. Other Jurassic and Cretaceous fossils are found in an unphosphatized or little phosphatized state, but these appear originally to have been included in a matrix of different character; for instance, fragments of the ferruginous Marlstone of the Middle Lias, full of *Rhynchonella tetrahedra,* do not seem to have been in any way altered. Phosphatized wood of palms and conifers is also associated in the Nodule Bed with fragments of silicified wood. The most abundant fossils consist of sharks' teeth and other remains from the London Clay, of teeth of many land mammals (pig, rhinoceros, mastodon, tapir, deer, hipparion, etc.), derived from some older Pliocene beds, and of many bones and teeth of marine mammals of like age, pieces of the ribs of whales being indeed among the most common things to be seen on the phosphate heaps, and earbones being not infrequent.

The only place where the Nodule Bed has been worked beneath the Coralline Crag is at Sutton, where, however, the pit did not prove remunerative, and was soon filled up. This section appears only to have been examined by Professors Lankester and Prestwich, and the following account is taken from their notes. Prof. Lankester merely mentions the occurrence of certain derivative mammalian bones, and of box stones, at the base of the Coralline Crag as well as under the Red Crag; Prof. Prestwich gives fuller particulars as to the character of the deposit.*

The old pit lay on the south side of Sutton-farm Hill, where the surface of the London Clay is 8 feet above the level of the River Deben. "Immediately on the London Clay we find a bed, from 1 to $1\frac{1}{4}$ foot thick, of Phosphatic nodules, not to be dis-

* *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 116. (1871.)

tinguished in general appearance from those of the Red Crag. Among them I found, as in the Red Crag, a great many fossil Crustacea, much worn, derived from the London Clay . . . . . With these I found one fragment of the horn of a Deer much mineralized, a small Cetacean vertebra retaining the ordinary bone-structure, together with numerous teeth of sharks. In the same bed were worn blocks of Septaria from the London Clay, drilled by boring mollusca, and flat, worn, highly mineralized Cetacean bones, superficially punctured, as those in the Red Crag, together with fragments of Bryozoa, *Terebratula grandis*, and *Cyprina*, much worn, and the latter full of the cavities made by minute boring sponges. With these organic remains there were a small number of the nodules or balls of coarse dark-brown sandstone, often containing the cast of a shell, so common in places in the Red Crag; there were also small pebbles of quartz and of flints, and some large pebbles of light-coloured, hard, siliceous sandstone: but the most remarkable specimen I there found was a rounded boulder of dark-red porphyry of considerable size, and weighing about a quarter of a ton. None of the specimens were angular or striated." Prof. Prestwich then gives a list of the most important specimens from this pit in the collection of Mr. Colchester; they were:—

One tooth of Mastodon (*M. arvernensis*).
Two milk-teeth of Rhinoceros (*R. Schleiermacheri*?).
Two teeth of Deer (*Cervus dicranoceros*).
Four teeth of Cetaceans.
One vertebra of Whale, large.
Two ear-bones of Whale; one mineralized, the other not.
Four skulls of *Belemnoziphius*.
Many teeth of *Carcharodon* and *Lamna*.
One vertebra of a Saurian (an extraneous fossil of Jurassic age).

"These are fossils identical with the species from the Red Crag; and, like them, they present a highly mineralized condition, and are, with the exception of some of the Cetacean and a few of the other Mammalian remains, all more or less rolled, worn, and polished."*

Under the Alluvium of Boyton Marshes Coralline Crag phosphate has also been worked, the water being kept down by pumping. Mr. A. Bell states that about 18 inches of Coralline Crag are overlain by Red Crag, and in working the labourers mix the two together. The admixture of Red Crag with Coralline Crag phosphate at this locality makes it impossible to separate the fossils with certainty, for the majority of the Coralline Crag shells show traces of a Red Crag matrix, proving that they come from a bed that has been reconstructed, and not from the undisturbed Coralline Crag Nodule Bed.

Though phosphatic nodules and phosphatized bones are of common occurrence at the base of the Red Crag, only over part

* *Op. cit.* p. 118.

of the district do they occur in sufficient abundance and sufficiently near the surface to be worth working. It is consequently only from a limited number of localities that the older fossils, with which we are especially concerned in this Chapter, have been obtained. A triangular area enclosed within a line drawn from Ipswich to the sea at Orford, and another to the Stour at Dovercourt, will include the whole of the district over which phosphate has been dug. As the sections of the Nodule Bed will be described with the Red Crag, it is unnecessary here to enter into details respecting them; it will be sufficient to mention that box-stones are especially abundant around Trimley, between the Rivers Orwell and Deben.

The materials included in the Nodule Bed may be classed under several heads. First we have the rocks and fossils belonging to periods older than the Tertiary. These are:—

Granite and igneous rocks.
Jurassic rocks and fossils.
Cretaceous fossils, large flints, Lower Greensand chert.

The next group includes undoubted Eocene fossils:—

Mollusca, many species
Crustacea, many species
Teeth of *Lamna* and *Otodus*
Coryphodon
Hyracotherium
Septarian nodules
} from the London Clay.

Then come a number of Upper Tertiary vertebrate remains, perhaps belonging to more than one period, and the box-stones. It is with this last group that we have now more especially to deal.

So many difficulties stand in the way of the separation of the various phosphatized bones into groups according to their geological age, that it will be advisable to deal first with the mollusca contained in the box-stones. The box-stones are rounded fragments of a peculiar brown sandstone, easily recognizable, and belonging, with little doubt, to a single horizon. The sand varies in fineness, but is usually somewhat coarse, many of the lumps containing small quartz pebbles; in fact it is just such a bed as might from its disintegration yield the coarse sand of the Red Crag. The cementing material is largely calcareous, but Mr. Teall, who has tested two samples, states that they are both also highly phosphatized, though from the quantity of sand contained in them they may be too poor to be worth working. Shells are abundant, but generally occur in the state of hollow moulds, the shell itself having been entirely removed by percolating water. These casts—as is the case in the Lenham ironstone—are often so sharp and well-defined that there is no difficulty in determining the species. Sometimes, however, the moulds have been subsequently filled with crystals of quartz, oxide of iron, or

with an earthy green mineral; in other cases a cement of carbonate of lime fills all the interstices between the grains of sand and partly occupies the place of the originally calcareous fossils.

The importance of the fauna included in the box-stones was first pointed out by Prof. Lankester, whose papers on the Nodule Bed and its contents, already cited, contain frequent references to the mollusca associated with the vertebrate remains; his last note on the subject contains a list of the species obtained up to the year 1870.* The following list of the mollusca identified up to the present time includes those found by Prof. Lankester and a few others since obtained:—

Mollusca from the Suffolk Box-Stones.

Bulla, sp.
Cassidaria bicatenata.
Conus Dujardinii.
Dentalium dentalis (= D. costatum).
Ficula reticulata (= Pyrula acclinis).
Nassa conglobata (some of the specimens belong to young Cassidaria, as Prof. Lankester has shown, but one or two appear to be correctly determined).
——— sp.
Natica, 2 sp.
Ringicula, sp.
Trochus ziziphinus.
——— sp.
Trophon, sp.
Turritella, sp.
Voluta auris-leporis.
——— Lamberti.
Abra, sp.
Astarte, sp. (not A. sulcata).
Cardium decorticatum.
Cyprina islandica.
——— rustica.
Glycimeris angusta.
Isocardia Cor (and var. lunulata).
Mactra, sp.
Mya, sp.
Panopæa Faujasii.
Pecten opercularis.
——— sp.
Pectunculus glycimeris.
Tellina, sp.
Venus, sp.

Of the 16 determined species from the box-stones all except two are well-known British Pliocene forms; the remaining two *Voluta auris-leporis* and *Conus Dujardinii* both occur in Pliocene beds on the continent. No doubt the mollusca show a decidedly warm climate—perhaps warmer even than that indicated by the fauna of Lenham, but at the same time there is not a single characteristic Miocene shell in the list, though most of the species range downwards into Miocene beds. As far as the mollusca go the evidence points to the box-stone fauna as belonging distinctly to very early Pliocene times.

The abundant remains of fish in the Nodule Bed are more difficult to deal with, for it seems to be quite impossible to separate by their mineralogical character or state of preservation the box-stone species from those derived from the London Clay. It may seem strange not to be able to separate Eocene from Pliocene specimens, but when we find thousands of teeth of *Lamna elegans*, in every state of preservation, from rolled fragments to perfectly unworn teeth, and find also that the species ranges through Eocene, Oligocene, and Miocene formations, there is nothing to show that some of the Nodule Bed specimens

* *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 493.

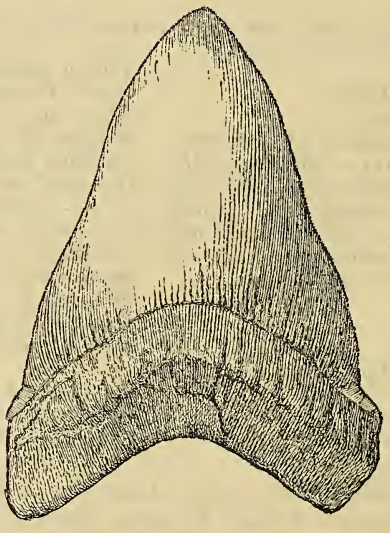
may not be contemporaneous with the shells, though the majority are undoubtedly derived from the underlying London Clay. A tooth of *Carcharodon megalodon* (Fig. 1) has been found imbedded

Fig. 1.

Carcharodon megalodon, Ag.

Half natural size.

(From a specimen retaining traces of the characteristic serrated margin, in the Museum of Practical Geology.)



in the box-stone matrix, and has been quoted as an indigenous fossil; other specimens of the same species may be of much older date, and even the specimen in a box-stone may have been originally washed out of an older deposit.

The mammals, having a more restricted range in time, are more easy to deal with, for we can at once put on one side *Coryphodon* and *Hyracotherium* as undoubtedly derived from Eocene strata. The other species from the Nodule Bed fall naturally into two groups—the cetacea and seals, and the land mammals. These are divided into several groups by Professor Ray Lankester, who is inclined to treat them as derived from various deposits of Miocene and Pliocene age, but I do not think there is any reason to consider that this derivative fauna belongs to more than two periods—the Lower Eocene and the Older Pliocene. The marine mammals, as far as yet determined, seem to correspond with those of the Diestian Sands of Antwerp.* The Diestian Sands and the box-stones are probably, however, so nearly of the same age, that there is no reason why the fauna

* There seems still to be some uncertainty as to the exact horizon from which many of the Antwerp cetacea have been obtained.

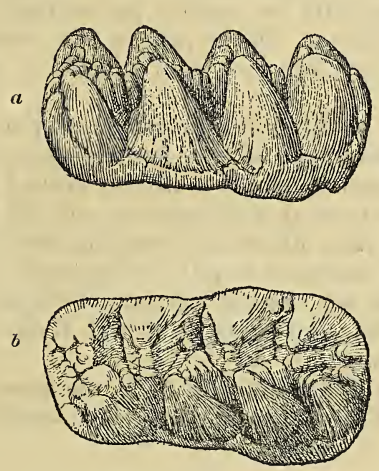
of the one should differ materially from that of the other, though we might expect to find the same species in different proportions, according to the known life-succession in Pliocene time. The older deposits should contain abundance of the southern species, while the newer should afford evidence of a preponderance of individuals belonging to more northern forms. In actual fact this preponderance is well shown by the mollusca of the box-stones. Besides the cetacea the Nodule Bed contains a Walrus, *Trichechus Huxleyi*, which occurs also in the Cromer Forest-bed.

The land mammals, as far as yet determined, are species found in Pliocene strata on the continent—such as *Mastodon arvernensis* (Fig. 2)—with the addition of a few still unknown except in the

Fig. 2.

Mastodon arvernensis, Cr. & Job.

Half natural size.



a. Side view of tooth. *b*. Grinding surface of same specimen.

Nodule Bed; none are exclusively Miocene. No land mammals having yet been discovered in the Coralline Crag or in the Diestian of Antwerp, we must guard against concluding from a comparison of the mammalian fauna of the Nodule Bed with that of the Forest-bed that they cannot both be Pliocene, for in this country most of the intervening links in the chain are missing. In the Appendix is given a complete list of the vertebrata from the Nodule Bed, but it may be observed that two or three of the species may possibly belong to the period of the Red Crag, of which deposit the Nodule Bed is merely the conglomeratic base.

Pits for "coprolite," or phosphatic nodules have constantly been alluded to in the previous pages. The raising of this material

being the only mineral industry of any importance connected with the Crag, it may be convenient here to give some further particulars relating to the economic value of the deposit. The mode of occurrence of the "Nodule Bed" has already been described. Its thickness varies considerably, for in many places there are only a few scattered lumps of the phosphate at the base of the Red Crag, while in others they form a seam as much as 18 inches thick. The usual thickness is less, pits seldom showing more than 10 or 12 inches. In working the Nodule Bed, the method adopted is to begin at the outcrop, and work with a long straight face toward the rising ground. The overlying Crag is removed in successive steps and thrown into the abandoned part of the pit, the surface being made good as the work goes on, so that the land may be again available for agricultural purposes as soon as possible. When a sufficient area of the Crag has been cleared away, the lowest portion, which contains the phosphatic nodules, is carefully removed and screened, and then hand-picked to get rid of the valueless part, such as the flints, quartzite pebbles, shells, and box-stones. Though the box-stones are phosphatized, they contain apparently too small a per-centage of phosphate of lime to be worth taking. In the process of screening all the small phospatic nodules are lost, but it is difficult to see how that can be avoided.

It is impossible to obtain trustworthy estimates of the available amount of phosphate, but no very large proportion has yet been removed. The depth at which it can be worked profitably varies greatly according to local circumstances and the market prices of the stone. More than 30 feet of overlying sands are removed at Foxhall, but this thickness is quite exceptional, and the working depends largely on the present low rate of wages in the district. There must be many square miles of the Nodule Bed within 30 feet of the surface.

No exact statistics are available as to the amount of phosphate raised; but Mr. W. Colchester has kindly supplied the following estimates :—

		Tons.			Tons.
1847	about	500	1877	about	10,000
1848	,,	1,000	1878	,,	10,000
1849	,,	3,000	1879	,,	4,000
1850	,,	5,000	1880	,,	5,000
1851	,,	6,000	1881	,,	5,500
1852	,,	8,000	1882	,,	5,500
1853	,,	10,000	1883	,,	5,500
1854	,,	12,000	1884	,,	7,800
1855 to 1857		Average about 9,000	1885	,,	6,000
			1886	,,	4,000
			1887	,,	2,000
1858	,,	10,000	1888	,,	3,000
1859 to 1876		Average about 9,000	1889	,,	5,000

In 1847 the "Coprolite" was first dug. In 1854 the Greensand "Coprolite" at Cambridge was discovered, and after that time the amount raised in Suffolk began to fall off. Mr. Colchester remarks that "the quality is wonderfully uniform, 56 per cent. of phosphate of lime. The average for Cambridge Coprolite is 58 per cent. phosphate but there is an excess of oxide of iron and alumina in the Suffolk, which accounts for the difference in price."

Dr. A. Voelcker, in his paper on Phosphatic Manures,* treats of the Suffolk Phosphates, and remarks that "in commercial phraseology, we have to understand by Suffolk-coprolites, or Crag-coprolites, or pseudo-coprolites, the mixed fossil bones, fish-teeth, and phosphatic pebbles which occur in the Suffolk Crag. These phosphatic matters are distinguished from the grey-coloured Chalk coprolites by a brownish ferruginous colour, and a smoother appearance. They are very hard, and yield on grinding a yellowish-red powder. Analysed in the manner usually adopted in commercial analyses, the composition of several samples of ground Suffolk coprolites may be illustrated by the following tabulated results:—

General Composition of Suffolk Coprolites.

——	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Moisture and a little organic matter	4·61	3·80	4·11	6·28	4·74
Phosphates - -	56·52	60·21	61·15	60·99	44·20
Carbonate of lime, magnesia, fluorine, &c. (determined by difference) - - - -	25·95	21·77	22·39	21·74	20·92
Insoluble siliceous matter -	12·92	14·22	12·35	10·99	30·14
	100·00	100·00	100·00	100·00	100·00

"In good samples of Suffolk coprolites the amount of insoluble siliceous matter varies from 10 to 14 per cent.; No. 5, therefore, appears to be a very inferior specimen.

"Besides fluoride of calcium, they contain a good deal of oxide of iron and alumina, which partially, at least, are thrown down with the phosphates when the latter are determined by precipitation with ammonia, as is usual in commercial analysis. In this case the amount of phosphates will be stated in excess. The true value of these pseudo-coprolites, therefore, can only be correctly estimated if the phosphoric acid which they contain is accurately

* On the Chemical Composition and Commercial Value of Norwegian Apatite, Spanish Phosphorite, Coprolites and other Phosphatic Materials used in England for Agricultural Purposes. *Journ. R. Agric. Soc.*, vol. xxi. pp. 359, 360. (1860.)

determined. This has been done in the subjoined analyses which at the same time represent their their detailed composition :—

DETAILED COMPOSITION OF SUFFOLK COPROLITES.

	No. 1.	No. 2.
Moisture and water of combination with a trace of organic matter	5·76	2·53
Lime	40·70	38·20
Magnesia	·34	1·34
*a*Phosphoric acid	28·32	24·24
Oxide of iron	4·87	4.81
Alumina		3·72
*b*Carbonic acid	5·08	5·37
Sulphuric acid	·87	1·40
Potash	·78	·56
Soda	·25	1·18
Chlorine	traces.	·07
Fluorine and loss	3·02	4·31
Insoluble siliceous matter	10·01	12·27
	100·00	100·00
(*a*) Equal to tribasic phosphate of lime (bone-earth)	61·30	52·52
(*b*) Equal to carbonate of lime	11·64	12·20

"No. 1, it will be seen, is a very superior sample: No. 2 represents a good average sample of Suffolk coprolites. In two other samples, in which the amount of insoluble matter and phosphoric acid alone was determined, I find :—

	No. 1.	No. 2.
Insoluble silicious matter	12·56	11·05
Phosphoric acid	23·48	24·26
Corresponding to bone-earth	50·87	52·56

It should be remembered that although phosphates have generally been worked only at the base of the Red Crag, they may yet be profitably dug also at the bottom of the Coralline Crag. Prof. Prestwich says that "it was only at one small pit [at Sutton], and there for a short time that the bed of phosphatic nodules at the base of the Coralline Crag was worked." He also tells us that "the condition . . . of the bones at the base of this Crag is precisely of the same character as that of those at the base of the Red Crag."

CHAPTER III.

CORALLINE CRAG.

Though the shelly sands locally known as Crag have been worked and their fossils collected from a very early period, it was not till 1835 that it seems to have been suspected that two distinct deposits with different faunas were included under this name. Previous observers took the Red Crag to be merely composed of the debris of the lower bed. In the year 1835 Mr. Charlesworth* read a paper in which the Crag was shown to be divisable into an upper, or Red Crag, and a lower, or Coralline Crag. The Coralline Crag was so named from the "Corals" (Bryozoa) found in it. They are repeatedly alluded to by Mr. Charlesworth, who, speaking of the pits at Sudbourn and Orford, mentions "the abundance of corals, many of which are extremely beautiful, and distinct from recent species. These corals sometimes occur in a loose sandy grit, from which they are readily detached; but it frequently happens that *the stratum is almost wholly constituted by them*, numerous species and genera indiscriminately growing upon one another, the interstices being filled with sand, dead portions of coral, comminuted shells, and other extraneous substances, all of which have become cemented together, occasionally forming a rock sufficiently compact for the purposes of building."

Mr. Charlesworth had thus at this early date thoroughly grasped the characteristic features of the deposit, and had not only done so but had recognised that the main mass at Sudbourne and Orford and the sections at Aldborough, Tattingstone, and Ramsholt all belong to one period, older than the Red Crag. The objection has since been made that true corals are rare in the Coralline Crag, and that the "corals" of Mr. Charlesworth are now known to be Bryozoa (Polyzoa); the terms Bryozoan Crag or White Crag have therefore been proposed. There seems, however, no reason for changing the very appropriate name given by Mr. Charlesworth, for in popular parlance bryozoa, such as occur so abundantly in the Coralline Crag (see Fig. 3), *are* corals, and one will often find marked on the Admiralty charts soundings with "coral"—meaning any coral-like organisms, either bryozoa, true corals, or gregarious tube-inhabiting annelids. Even long

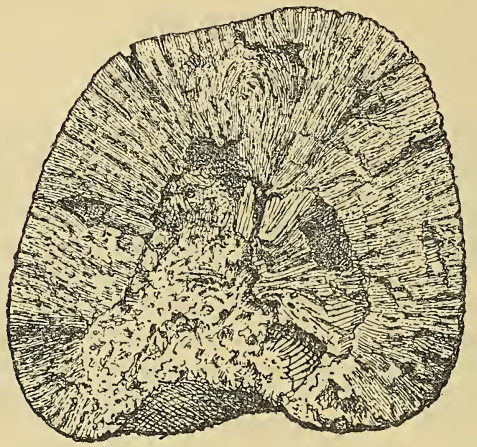
* *Phil. Mag.*, ser. 3, vol. vii. pp. 81–94. (1835.) Abstract in *Proc. Geol. Soc.*, vol. ii. No. 41, pp. 195, 196.

after the date of Mr. Charlesworth's paper Lyell speaks of the characteristic Crag bryozoa as "corals."

Fig. 3.

Fascicularia aurantium, M. Edw.

Natural size.



After the publication of Mr. Charlesworth's paper there was a good deal of discussion as to the accuracy of his views. The controversy is now of little interest, but anyone wishing to follow it will find the titles of all the papers in the Appendix. It may be observed, however, that Lyell almost immediately accepted the proposed names, maintaining, however, that both beds belonged to one period. A few years later Lyell* visited the Crag district, and was able to give a description of the marked unconformity between the two deposits. He, however, now agreed with Desnoyers in considering both beds to be contemporaneous with the Faluns of Touraine. The principal points of interest in his paper—as far as the Coralline Crag is concerned—are the full descriptions of the Sutton and Tattingstone sections, in both cases drawn up after special excavations had been made.

Most of the papers about this date refer especially to the upper division, and the next advance is marked by the publication of the first part of Searles Wood's Monograph of the Crag Mollusca.† In this monograph the author speaks of the Coralline Crag as Miocene, and of the Red Crag as Pliocene, but on the completion of the work he inclined to refer both to the Pliocene period.‡

From 1848 onward numerous monographs on the different classes of fossils in the Crag were published by the Palæontographical Society. Besides the splendid work on the Mollusca

* On the Relative Ages of the Tertiary Deposits commonly called "Crag," in the Counties of Norfolk and Suffolk. *Mag. Nat. Hist.*, n. ser., vol. iii. pp. 313–330. (1839.)

† *Palæontographical Society*, 1848.—Introduction, p. v.

‡ *Ibid.*, 1856, pp. 301, 302.

just mentioned, Milne-Edwards and Haime described the Corals in 1850, Darwin the Cirripedes in 1851 and 1855, Forbes the Echinodermata in 1852, Professor T. R. Jones the Entomostraca in 1857, Busk the Polyzoa in 1859, Professors Jones and Parker and Mr. Brady the Foraminifera in 1866. All these monographs, as well as various scattered papers on particular fossils, contained information which helped to advance the knowledge of the nature and age of the deposits and of the conditions under which they were laid down; but of stratigraphical papers or of notes relating directly to the physical character of the beds there were few. Wood,* however, in 1854, when describing some curious tubular cavities in the Coralline Crag, incidentally gave some additional particulars of the extent and lithological character of this division.

In 1865 Professor E. Ray Lankester† gave a sketch of the general character and extent of the Crags. The first part of this paper has been referred to in the previous chapter. The second part dealt with the correlation of the Crags of Antwerp and England, concluding from the per-centage of extinct mollusca in each deposit "that the Red and Coralline Crags of Suffolk and the Upper Crag of Antwerp are far more closely connected with each other than any one of them is with the Middle or Lower Crag, or than these latter are with each other; and on this account the Red, Coralline, and Upper Antwerp Crags may be considered as Upper Pliocene; the Middle Antwerp Crag, as Middle Pliocene; and the Lower or Black Crag, as Lower Pliocene." Further on Professor Lankester pointed to the derivative mammalian remains in the Red Crag as probably being the debris of an older formation of the age of the Middle Crag of Antwerp—otherwise unknown in England—no equivalent being found in this country of the Lower Antwerp Crag, which he referred to the Upper Miocene Period and correlated with beds at Bordeaux and Vienna.

In the same year S. V. Wood, jun.,‡ issued a Map of the Upper Tertiaries in the counties of Norfolk, Suffolk, etc. On this map the Coralline Crag was for the first time separated from the newer deposits; the accompanying remarks, however, refer almost entirely to the later beds.

Next year, S. V. Wood, sen.,§ speaking of the relation of the Red to the Coralline Crag, writes: "In the case of the Coralline Crag, we have evidence that it contains the exuviæ of animals the most removed from our own marine fauna, in the fact that in it are the remains of 27 genera that are extinct in the British seas . . . . From this it is fair to infer that this Crag belonged to a period long antecedent to the deposition of the Red. Indeed so far as the word 'Crag' indicates any material affinity between the

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* *Phil. Mag.*, ser. 4, vol. vii. p. 320.

† On the Crags of Suffolk and Antwerp. *Geol. Mag.*, vol. ii. pp. 103, 149.

‡ *Privately printed.* An abstract of the remarks in explanation in *Quart. Journ. Geol. Soc.*, vol. xxi. p. 141.

§ On the Structure of the Red Crag. *Ibid.*, xxii. p. 541.

two formations, it misleads, since, remote as it is, and severed from the present time by a considerable sequence of deposits and events, the oldest part of the Red Crag is less removed, palæontologically, from the present time (and far less so from the Chillesford beds) than it is from the Coralline Crag thus associated with it in name, but dissociated from it in fact." I have quoted this passage in full, for it appears to be one of the earliest instances in which an observer in this country was able to shake himself free from the fetters of mere numerical statistics in dealing with the Crag faunas. Wood, putting on one side the method of fixing the age of a Tertiary deposit by the proportion that it contains of species living in any part of the world, points to broad differences in the general characters of the Coralline and Red Crag faunas, and to the great contrast of the older one to that of the Red Crag or that now inhabiting the British seas. He realizes that extensive climatic changes and migration show a lapse of time and are good grounds for distinction, though the vanished species may still be found living in other parts of the world.

About this date there was a good deal of discussion as to the correlation of the English and Belgian Crags, but the arguments have lost their force now that it is known that the Scaldisian, Diestian, and Miocene faunas were not always properly separated. The principal papers were by R. A. C. Godwin-Austen,* Prof. E. Ray Lankester,† and Prof. A. von Koenen.‡

The next paper containing new facts relating to the Coralline Crag was published in 1868 by Prof. Lankester.§ This communication deals principally with the mammalian remains found at the base of the Crags and has already been referred to in connexion with the difficult question of their origin (p. 8).

Later in the same year Godwin-Austen, in his address to the geological section of the British Association,‖ again dealt with the physical conditions under which the Crags on both sides of the North Sea were deposited. He assigned the Coralline Crag to a depth of 40 fathoms, and spoke of it as "the lowest condition, or the deepest, of which our English area offers any illustration."

In 1870 Prof. Lankester¶, after pointing to the probable source of the mammalian remains in the various bone-beds of Norfolk and Suffolk, gave a full list of the fossils found in the "box-stones." This important paper has been referred to in the previous chapter. Prof. Lankester concluded that the box-stones and their fossils belong to an older period than either the Coralline or Red Crag.

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* On the Kainozoic Formations of Belgium. *Quart. Journ. Geol. Soc.*, vol. xxii. p. 228. (1866.)

† On the Crags of Suffolk and Antwerp. *Geol. Mag.*, vol. ii. pp. 103, 149 (1865); Are the Coralline Crag of Suffolk and the Black Crag of Belgium contemporaneous Deposits? *Ibid.*, vol. iv. p. 91. (1867.)

‡ On the Belgian Tertiaries. *Ibid.*, vol. iv. p. 501. (1867.)

§ The Suffolk Bone-bed and the Diestian or Black Crag in England. *Ibid.* vol. v. p. 254.

‖ *Geol. Mag.*, vol. v. p. 469, and *Rep. Brit. Assoc.* for 1868, and *Geol. Nat. Hist. Repertory*, vol. ii. p. 229.

¶ *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 493.

Next year appeared Prof. Prestwich's important series of papers on the structure of the Crag beds.* The first of these—that on the Coralline Crag of Suffolk—had been read before the Geological Society in 1868 and is several times alluded to in Prof. Lankester's paper published somewhat later in that year. Prof. Prestwich gave full details of the different Coralline Crag pits, adding a map of the outlier at Sutton and levelled sections across the hill. He concluded that several zones could be traced in the Coralline Crag, though the higher ones sometimes overlap the lower so as to rest on the London Clay. The total thickness was taken to be about 76 feet, and in a generalized section the following divisions were made:—

		Feet.
Upper Division, 36 feet.	*h*. Sand and comminuted shells	6
	g. A series of beds consisting almost entirely of comminuted shells and remains of Bryozoa, forming a soft building-stone. False stratification and oblique bedding are its constant characters	30
Lower Division, 47 feet.	*f*. Sand with numerous entire small shells and seams of comminuted shells	5
	e. Sands with numerous Bryozoa, often in the original position of growth, and some small shells and Echini	12
	d. Comminuted shells, large entire or double shells, and bands of limestone in the upper part	15
	c. Marly beds with numerous well-preserved and double shells, often in the position in which they lived	10
	b. Comminuted shells, Cetacean remains, Bryozoa	4
	a. Phosphatic nodules and mammalian remains	1

In a later paper a slight correction is made—"It is possible that the estimate for bed '*e*' may be 2 feet, and for bed '*d*' 5 feet, too thick, which would make the thickness of the lower division of the Coralline Crag about 40 instead of 47 feet."

Under the heading "General Considerations" Prof. Prestwich gives an account of the history of the Older Pliocene strata, and of the physical changes which took place in the Anglo-Belgian basin during the Miocene and Pliocene periods. He then points to the varying conditions under which the different portions of the Coralline Crag were deposited, and traces the changes indicated by the beds overlying the Nodule Bed thus: "As the land subsided the coarser materials of the basement-bed were covered up by a bed of comminuted shells. This subsidence continuing, beds '*c*' and '*d*' were deposited in comparatively deep and tranquil water. These beds are succeeded by the sands '*e*,' abounding in Bryozoa, with small Echini, and a number of small bivalves, indicating apparently the greatest depth of sea (possibly of from 500 to 1,000 feet) attained during the Coralline-Crag period. A change then took place, and a bed of comminuted

* *Quart. Journ. Geol. Soc.*, vol. xxvii. pp. 115–146.

shells, with occasional oblique lamination, was spread over this deep-sea bed, indicating possibly a shallowing of the sea by a reverse movement of elevation, and the setting in of stronger currents with intervals of quiet deposition. Further elevation, exposing the sea-bed to the action of tides and currents, led to considerable wear and denudation of the lower beds and to the heaping up of the remains of Bryozoa and of Mollusca of beds '*f*' and '*e*' in banks over portions of the sea-bed. Under such conditions the upper division '*g*' of the Coralline Crag seems to have been generally formed; at a few places only do some of the beds seem to have been formed tranquilly."

"Bed '*h*' shows, in the finer state of comminution of the shells and Bryozoa, that the water probably continued to get shallower; and finally a continuance of the same movement of elevation gradually raised the Coralline Crag above the sea, and exposed it to the denuding action which has removed so large a portion of it. Then, or during the Red-Crag period immediately following, the Coralline Crag was broken up into detached islands and reefs, amongst which the Red Crag was deposited during a period of slow and small subsidence."

To this paper is added a full list of the Coralline Crag mollusca, with the determinations revised by Gwyn Jeffreys. Comparisons are also made between the Coralline Crag fossils and the fossils of various continental Pliocene deposits, and also with the living faunas of different seas. The conclusion come to is that a much larger proportion of the Coralline Crag mollusca belongs to recent species than was allowed by Searles Wood, and that the Coralline Crag contains a good many northern forms not recognised by that author. Thus the fauna is made to appear more like that now inhabiting the British seas, and less like that of the Mediterranean, than had generally been thought.

Next year (1872) Messrs. S. V. Wood, jun., and F. W. Harmer* gave a general description of the Coralline Crag, without entering into much detail of the sections. As the divisions adopted by them are somewhat different from those suggested by Prof. Prestwich, it will be desirable to quote their account, especially as it is founded on the life-long work of S. V. Wood, senr. After indicating the known extent of the deposit—which had scarcely been traced beyond the limits within which Mr. Charlesworth first described it in 1835—they mention a trace "at Trimley, where it was observed in the digging of a ditch by the late Mr. Acton." If this note is accurate it carries the Coralline Crag 4 or 5 miles south of the furthest point to which it had previously been followed.

Messrs. Wood and Harmer's general description of the Coralline Crag is as follows: "The Coralline Crag has long been known to consist of two main portions, and a third subordinate bed. The first and lowest of these consists of a series of calcareous

* An Outline of the Geology of the Upper Tertiaries of East Anglia [with Map], in the Supplement to the Crag Mollusca. *Palæontographical Society*. (1872.)

sands, in some places more or less marly, which are rich in Molluscan remains. The second consists of a solid bed formed of Molluscan remains, agglutinated with the fronds and fragments of various species of Polyzoa into a rock, so hard as to have been formerly quarried for building. The third and uppermost is a thin subsidiary bed, consisting of a few feet of the abraded material of the rock, reconstructed evidently in very shoal water, probably, indeed, between tide marks, as it is very obliquely bedded.

"From the outliers at Tattingstone and Ramsholt this rock-bed is absent, but over the Sutton outlier a small cap of it remains Over the main mass, however, it spreads continuously, and either from a slight northerly dip of the whole formation, or else from a displacement of the underlying shelly sands, this rock-bed descends to the sea-level at the northern extremity of the mass." The authors then criticise the method by which an estimated thickness of between 80 and 90 feet had been obtained for this formation, and consider that "the place to test the true thickness of the formation is clearly that where it is in the greatest state of preservation. . . . . Estimated in this way, it will be difficult to make out the thickness of the Coralline Crag as exceeding sixty feet."

Messrs. Wood and Harmer object to Professor Prestwich's division of the lowest portion, the shelly sands, into constant and determinable horizons, characterized by special groups of fossils, and remark that "the author of the 'Crag Mollusca' in his long researches has mainly confined himself to one pit at Sutton, affording a vertical range of but a very few feet, and yet from this spot he has obtained specimens of nearly the whole known species of the Coralline Crag, many of these being known to collectors as occurring only at the pits near Orford. Not only this, but so inconstant is the Molluscan facies at any one place, that many species which once occurred at this spot (and some of them abundantly) have not been noticed there for many years. An attempt under such circumstances to group these shelly beds in any order of Molluscan succession would thus evidently be illusory."

Prof. Prestwich had estimated the depth of water under which this Crag was accumulated at "possibly from 500 to 1,000 feet;" but S. V. Wood, sen., "considers that nothing among the forms of Mollusca yet obtained from the Crag, points to the existence of any greater depth of water for their habitat than 35 or 40 fathoms, so that, coupling the physical difficulties with the exigencies of the molluscan evidence, we may, we think, regard the depth of the Coralline Crag sea of Suffolk as under 300 or even 250 feet, rather than as approaching 1,000."

In the same year (1872) Messrs. A. and R. Bell gave some additional details of certain of the Coralline Crag sections, and a long catalogue of the fossils from the "Lower Crag," as the Coralline Crag is named in their papers.*

* On the English Crags and the Stratigraphical Divisions indicated by their Invertebrate Fauna. *Proc. Geol. Assoc.*, vol. ii. No. 5, p. 185. Supplement by A. Bell, No. 6, p. 270, and The Succession of the Crags. *Geol. Mag.*, vol. ix. p. 209.

S. V. Wood, sen., in his concluding remarks at the end of the Supplement to the Crag Mollusca* (1874), criticises Jeffreys' identifications of many of the Coralline Crag species with recent, especially with arctic, forms, and maintains the accuracy of most of his own determinations. He observes that "it is obvious that this author's leanings are very marked, so as to group together allied Crag forms as varieties only of one species, and especially to make out a Crag shell to be either identical with a living species, or, at most, only a variety of it whenever the slightest presumption can be found for that course." Wood also points out that "another reason for not undervaluing even slight differences by which many of the Crag Mollusca are separable from their living analogues, and so reducing them to the inferior importance supposed to be possessed by the term 'variety,' exists in the discordance between the evidence presented by the Molluscan fauna when thus reduced, and that presented by the other organisms of the Crag period." He, therefore, is still of the opinion, held also by Forbes and Hanley, that the Molluscan fauna of the Coralline Crag has its affinities chiefly with that of the Mediterranean. To this Monograph is added a Synoptical List of the Crag mollusca, in which is also given the geographical range of all the species which Wood recognizes as still living.

In 1879 Wood published a second supplement to his Monograph, and in 1882, after his death, appeared the third supplement, edited by his son. To the third supplement S. V. Wood, jun., added some further notes on the physical conditions under which the Crag was deposited, and on the correlation with other deposits on the continent.

During the years 1882–3 the maps of the Geological Survey† appeared. These showed the boundaries of the formation more accurately than before; but no fresh outliers had been discovered, though sunk rocks of Coralline Crag are noted as occurring off Thorpe and Sizewell, on the authority of Mr. C. P. Ogilvie.

Mr. P. F. Kendall,‡ in 1883, drew attention to the fact that whilst the shells in a pit near Aldborough were, with one exception, of the kinds determined by Dr. Sorby to have their carbonate of lime in the calcite form, the many casts are, without exception, of the kinds in which the carbonate of lime is in the form of aragonite. Aragonite, though harder and of higher specific gravity than calcite, is a less stable substance, and is much more easily acted upon by carbonated water. He adds that "the consolidation of the Coralline Crag, and the dissolution of the aragonite shells, appears to have taken place previously to the deposition of the Red Crag, or at any rate of the middle part of it, as I have found a fragment of Coralline Crag with shells and casts in the coprolite diggings at Boyton."

During 1885 and 1886 were published the two Memoirs of the Geological Survey, in which Messrs. Whitaker and Dalton

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* *Palæontographical Society.*

† Sheets 48 N.E. and N.W., 49 S.W., 50 S.E.

‡ *Geol. Mag.*, dec. ii., vol. x. p. 497.

described the whole of the Coralline Crag district.* Most of their notes will be found incorporated in this chapter.

The Coralline Crag, though occupying so small an area, is a formation of considerable importance to the geologist, owing to its extremely varied fauna and exceptional lithological character; it must, therefore, be described more fully than will be necessary with some of the other divisions of the Pliocene series. As the Geological Survey, however, has been able to add little to our knowledge of this bed, and as many of the older observers saw sections now invisible, and in many cases had pits dug so that they might more thoroughly study the deposits, the following account of the sections in the Coralline Crag must be largely taken from the work of previous observers. Use therefore has been freely made of the published papers by Mr. Charlesworth, Lyell, Prof. Prestwich, and S. V. Wood, sen. and jun., especially where their notes refer to better sections than are now visible, but at the same time, that the student may not be led to search for pits long since overgrown, a note is added of the present state of the exposures. All the localities were re-examined by the writer of this Memoir in 1886 and 1889.

Commencing at the northern extremity of the formation, the first indications of Coralline Crag are the sunk rocks off Sizewell and Thorpe. Two or three miles further south the Crag was formerly seen under the beach at Aldborough, but the sections are now sloped and built over, and this is the only place where the deposit has been found on the coast.

Inland at Aldborough, near the Red House, there are pits on both sides of the high road. Another pit will be found about 100 yards north of Aldborough Hall, and from this was obtained the very perfect crab (*Cancer pagurus*) now in the Museum of Practical Geology. Further west, on the north bank of the River Alde, opposite Stanny Point, the Coralline Crag forms a low cliff of loose brashy rock. The pits near Aldborough are not good places for collecting, as the aragonite fossils are usually only in the state of casts, though bryozoa are often particularly well preserved. Crustacea also would seem to be exceptionally perfect, for besides the crab already mentioned, Prof. Prestwich speaks of a beautiful specimen, found by Mr. Norman Evans, probably referable, according to Dr. H. Woodward, to *Gonoplax angulata*, Leach. Prof. Prestwich thinks that near Aldborough the upper division of the Coralline Crag is alone exposed; all the pits are certainly in rubbly limestone of the same character, and the base of the deposit is nowhere reached.

On the south side of the River Alde, these beds reappear at a somewhat higher level, so that the upper part of the lower division skirts the marsh. At Iken Brickfield, about half a mile west-north-west of Calton Farm, Prof. Prestwich recorded† thirty

* Ipswich, Hadleigh, and Felixstow (1885), and Aldborough, Framlingham, Orford, and Woodbridge" (1886).

† *Quart. Journ. Geol. Soc.*, vol. v. p. 347 (1849).

feet of Coralline Crag underlying the Red Crag. Only about eight feet could, however, be seen in 1886. The beds belong to the upper division with casts of shells, but the only section being in the middle of the pit, where the newer deposits have been entirely removed, the junction with the Red Crag cannot at present be examined. Mr. Dalton speaks of the beds near Redland's Covert as consisting of firm stony Crag, a mass of shells and casts, false-bedded at top and bottom, but not in the intermediate beds. Among the shells *Mytili* largely predominate, forming here and there the entire mass of considerable slabs. Near the top are concretionary masses, and a few Bryozoa. Bands of tufa occupy crevices and bedding-planes of open texture. Other sections of Coralline Crag will be found at Calton Farm, and at a "Crag Pit" (marked on the map) half a mile to the west. The latter shows 10 feet of false-bedded rubbly limestone full of Bryozoa and broken Echinoderms.

The rock-bed is, or has been, quarried at several points along the base of the Red Crag to the east-north-east of Sudbourn Church; the sections are of no great interest, but the exact position of each will be found indicated on the maps of the Geological Survey. At the cross-roads, four-fifths of a mile north-north-east of Sudbourn Church, is a large pit showing twenty feet of false-bedded buff Bryozoan sand or soft limestone. Whole shells are rare in this pit, and in the upper part of the section they are only found in the state of casts. The pit close to Sudbourn Church (on the west side) shows a very good section of soft Bryozoan limestone, with *Fascicularia* near the top.

Following next the road from Sudbourn Church to the Hall, a large pit will be found, exactly opposite the Park gates, in the angle of the roads to Chillesford and Snape. It is now not often worked, but shows extensive vertical faces of soft rock on which perfect Bryozoa weather out. *Pecten opercularis* is an abundant shell here; other mollusca are not plentiful. While examining this section, I found a piece of drift-wood—too much decayed for microscopic examination—and a large splinter of mammalian bone, probably Cetacean.

In Sudbourn Park old overgrown pits will be seen on each side of the road to the Hall. Several of these have been described by previous writers, but as the sections are not now visible, and they did not show anything exceptional, it is needless to repeat the details. One pit in the Park is still open, the "Crag Pit," marked on the map, on the low ground north-west of the Hall. This is a large shallow pit in loose calcareous sand or marl, which is still extensively dug for making paths. Unlike the beds met with further north, the sand is full of well-preserved mollusca. Large and perfect specimens of *Cardita senilis* and *Cyprina islandica*, often with the valves united, are abundant, and many fine specimens of *Terebratula grandis* have been found, though this last species is nowhere plentiful. A box of the sand was taken by me to London for more minute examination, but the results were somewhat disappointing, for the minuter forms

of mollusca were very scarce, though shells down to the size of the smaller species of *Cardita* and *Astarte* occurred in large numbers. Scattered grains of glauconite were fairly numerous in the sand. Mr. Dalton observes that in this pit the surfaces of the thin irregular bands of limestone are covered with delicate bryozoa, indicating probably the contemporaneous deposition and solidification of the stone.

Following next the eastern margin of the Coralline Crag hill, the pit south of Ox House, above Sudbourn Marshes, is now used as a cattle yard. It shows vertical walls of soft false-bedded limestone, much overgrown by lichens. The rock-bed was also formerly quarried at Roydon Cottage and Roydon Hall Farm, but these pits have now been ploughed over. A large pit will be found close to Orford Castle, though here the rock-bed is reached beneath a considerable thickness of sand—probably Red Crag—which slips and greatly obscures the section. South of Orford, in the stock-yard of Richmond Farm, there is a good section of false-bedded limestone, composed of comminuted shells; the only perfect fossils observed were a few *Anomias* and a fish otolith.

About half a mile further south, at High House and Low Farm, Gedgrave, there are three pits. The highest of these is in the rock-bed, but is now seldom worked. The middle one shows the base of the shell-limestone, seen at Richmond Farm, resting on an underlying shelly sand with perfect mollusca. The lowest pit is at the edge of the Marsh at Low Farm, and is worked down to the water-level. It shows false-bedded, white, cream-coloured, or buff calcareous sand, full of small shells and broken Bryozoa. The buff colour of the beds seems to be due to infiltration from above, for under inverted oyster-shells the sand is pure white. One or two phosphatic nodules were observed scattered through the Crag, but they are not abundant. This pit should be noted as probably the best now open, except that at Sutton, for the collection of the more minute shells, especially univalves. Small *Scalaria* and *Rissoa* of several species are plentiful; among the bryozoa *Salicornaria* and *Eschara monilifera* are very abundant. The larger mollusca are here principally oysters and scallops.

Between Gedgrave Marshes and Ferry Farm another pit has been opened in the same shelly beds, but the section is small and obscure. It shows four or five feet of false-bedded calcareous sand with thin bands of rubbly limestone. Small shells are abundant, including *Cypræa europæa* and *Odostomia*.

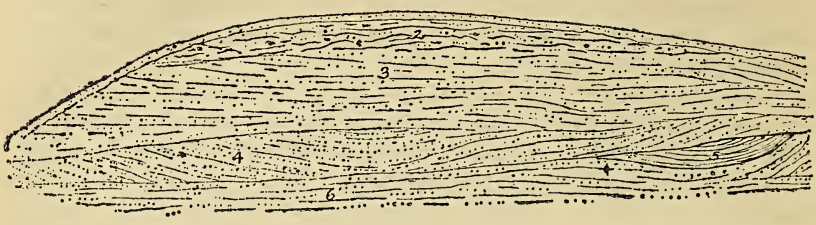
On the west side of the hill the two sections remaining to be described are perhaps the best known of any in the Coralline Crag. The most northerly of these is the "Broom Pit," near the Keeper's Lodge, and nearly a mile west of Orford. This pit is a good deal worked and shows a clear vertical face of twenty feet, though none of the beds are hardened into limestone. S. V. Wood and S. P. Woodward both made extensive collections here, and Prof. Prestwich described the section in his paper on the Coralline Crag.* The following sketch (Fig. 4) was made by me in 1886.

* *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 122. (1871.)

Fig. 4.

Broom Pit, near the Keeper's Lodge, Gedgrave.

Scale, 20 feet = 1 inch.



1. Soil.
2. Calcareous sands and rubbly limestone, crowded with Bryozoa, especially large masses of *Fascicularia*. A few perfect small shells.
3. Calcareous sands with scattered *Fascicularia* and other Bryozoa, and small shells.
4. False-bedded calcareous sand, with broken shells, mostly at the base. Perfect valves of *Psammobia*—high up, lower down *Cardium decorticatum*, *Pecten opercularis*, *P. Gerardi*, *Nucula nucleus*, &c.
5. Similar sands, with a thin bed of hard marly limestone at the base.
6. Shell beds. Large shells abundant, especially in the lower part. *Cyprina islandica*, *C. rustica*, *Thracia*, *Panopœa*, *Pectunculus*, *Pecten maximus*, &c. Cetacean vertebra at point marked +. (This is the bed from which most of the shells are obtained.)

Prof. Prestwich considers that the lower strata here belong to his zone *d*, while the upper ones represent the lower part of zone *e*. As an example of the fauna from a single locality it may be interesting to give the following list of the mollusca obtained by S. P. Woodward in 1863 from the Broom Pit. He remarked that bivalves were abundant; univalves, except *Turritella incrassata*, comparatively scarce.

Broom Pit, Gedgrave.

Adeorbis striatus.
Buccinum undatum.
Cæcum mammillatum.
Calyptræa chinensis.
Cypræa europæa.
Emarginula fissura.
Fissurella græca.
Margarita trochoidea.
Natica proxima.
Rissoa crassistriata.
Scalaria clathratula.
——— subulata.
Turritella incrassata.
Trochus formosus.
——— ziziphinus.

Anomia ephippium.
——— striata.
Astarte Basteroti.
——— Burtini.
——— gracilis (A. Galeotti).
——— mutabilis.
——— Omalii (abundant).
Cardita corbis.
——— orbicularis.
——— scalaris (abundant).
——— senilis (abundant).
Cardium decorticatum.
——— strigilliferum.
Corbula nucleus (C. gibba).
Crenella sericea.
Cyprina islandica (abundant).
——— rustica.
Cytherea chione.
——— rudis.
Diplodonta rotundata.
Glycimeris angusta.
Leda semistriata.
Lima Loscombii.
Limopsis aurita.
Lucina borealis (abundant).
——— crenulata.
Lucinopsis Lajonkairii.
Mactra arcuata.
Mya truncata.
Mytilus hesperianus.

Nucula nucleus.
Ostrea edulis.
Panopæa Faujasii (abundant).
Pecten Gerardi.
——— maximus.
——— opercularis (abundant).
——— pusio.
——— tigrinus.
Pectunculus glycimeris (abundant).
Pinna pectinata.
Psammobia ferroënsis.
Solen ensis.
Tellina donacina.
——— obliqua.
Thracia inflata.
——— ventricosa.
Venus casina (abundant).
——— imbricata.
——— ovata.
Verticordia cardiiformis.

Lingula Dumortieri.
Terebratula grandis (abundant).

About three-quarters of a mile further south the Butley River has cut into the Coralline Crag hill, so as to make a low cliff near Ferry Cottages. The section thus exposed is not good, though it shows shelly sands reaching to about 9 feet above the water-level. The well-known "Gomer Pit" lies in the field above, but the name does not appear in the 1-inch Ordnance Map. This pit is occasionally opened for the purpose of obtaining Coralline Crag fossils, which are perhaps here found more abundantly, better preserved, and of greater variety than in any other section of equal extent. As the pit is only worked for the fossils, it is generally ploughed over in the summer time, and can very seldom be examined. The deposit consists of shelly sand, referred by Prof. Prestwich to his division *d*. Dr. S. P. Woodward, in 1863, spent a good deal of time here, and the following list of fossils then collected has been communicated, like the last, by his son, Mr. H. B. Woodward, who assisted him. The pit is described as very rich in species, univalves and bivalves.

Gomer Pit, Gedgrave.

Adeorbis pulchralis.
——— striatus.
——— supra-nitidus.
Aporrhais pes-pelicani.
Bela concinnata.
Buccinum Dalei.
——— undatum, var.
Bulla conuloidea.
——— lignaria.
Cæcum glabrum.
——— mammillatum.
Calyptræa chinensis.
Cancellaria mitræformis.
——— scalaroïdes.
Cassidaria bicatenata.
Cerithium adversum.
——— granosum.
——— trilineatum.
——— tuberculare, var.
Chemnitzia elegantissima.
Cylichna cylindracea.
Cypræa europæa.
——— retusa.
Dentalium bifissum.
——— costatum.
Emarginula crassa.
Emarginula fissura.
Erato lævis.
——— Maugeriæ.
Eulima subulata.
Fusus alveolatus.
——— consocialis.
——— gracilis, var. propinqua.
Lacuna reticulata.
Mangelia cancellata.
——— castanea.
——— costata.
——— mitrula.
——— perpulchra.
Margarita ? maculata.
——— trochoidea.
Murex corallinus.
Nassa consociata.
——— granulata.
——— labiosa.
——— prismatica.
Natica cirriformis.
——— multipunctata.
——— proxima.
——— varians.
Odostomia plicata.
——— truncatula ?

Ovulum spelta ?
Pileopsis ungaricus.
Pleurotoma porrecta.
——— semicolon ?
——— ——— var.
Pyramidella læviuscula.
Rissoa confinis.
——— obsoleta.
Scalaria cancellata.
——— clathratula.
——— foliacea.
——— frondicula.
——— subulata.
——— varicosa.
Terebra canalis.
——— inversa.
Triton heptagonum.
Trochus Adansoni.
——— granulatus.
——— Kicksii.
——— millegranus.
——— obconicus.
——— tricariniferus.
——— villicus ?
——— ziziphinus.
Trophon muricatus.
Turritella incrassata.
Voluta Lamberti.

Anomia ephippium.
——— striata.
Arca pectunculoides.
Astarte Basteroti.
——— Burtini.
——— ? digitaria.
——— gracilis.
——— mutabilis.
——— Omalii.
——— parva (A. Forbesii).
——— parvula.
——— triangularis.
Cardita corbis.
——— orbicularis.
——— scalaris.
——— senilis.
Cardium decorticatum.
——— nodosum.
——— strigilliferum.
Circe minima.
Corbula nucleus.
Cryptodon sinuosum.
Cyprina islandica.
——— rustica.
Cytherea rudis.
Diplodonta dilatata.
——— rotundata.
Donax politus.
Erycinella ovalis.
Gastrana laminosa.
Glycimeris angusta.
Kellia ambigua.
Leda pygmæa.
Lima exilis.
——— subauriculata.
Limopsis aurita (rare).
——— pygmæa.
Lucina borealis.
Lutraria elliptica.
Mactra obtruncata,
——— triangulata.
Modiola marmorata.
——— phaseolina.
Montacuta bidentata.
——— ferruginosa.
——— substriata.
——— truncata.
Nucinella miliaris.
Nucula lævigata, var.
——— nucleus.
——— tenuis ?
Ostrea edulis.
Pecten Gerardi.
——— maximus.
——— opercularis.
——— pusio, var. striata.
——— similis.
——— tigrinus.
Pectunculus glycimeris.
Pholadomya hesterna (?).
Pinna pectinata.
Saxicava ? carinata.
Solen ensis.
Syndosmya prismatica.
Tellina donacina.
——— obliqua.
Thracia inflata.
——— phaseolina.
Venus casina.
——— imbricata.
——— ovata.

Terebratula grandis.

Cellepora edax.
Cupularia porosa.
Hornera infundibulata.

Balanus bisulcatus (common on Lucina and Pecten Gerardi).
Balanus concavus (retaining colour).

Ditrupa subulata.

This completes the description of the main mass of the Coralline Crag, but on the west side of the Butley River there is perhaps a foot or two of the basement-beds under Boyton Marshes, where it is worked for phosphate. These sections have already been spoken of in the last chapter. It now only remains

to allude to the few small scattered outliers which form the whole of the rest of the Coralline Crag, but altogether do not occupy so much as a single square mile.

South-west of Boyton a wide plateau of newer deposits may possibly conceal extensive outliers of Coralline Crag, though none have yet been met with; there appear to be no wells sunk to a sufficient depth to reach them if they exist there. Following the edge of the plateau, where the London Clay outcrops, no trace of Coralline Crag has been found except at Sutton and Ramsholt, close to the River Deben. These two outliers lie close together, one on each side of Shottisham Creek, at the point where it joins the Deben. They, not improbably, are remains of one outlier, which has been cut in half by the Creek in comparatively recent times.

The small outlier at Ramsholt was formerly to be seen in the low cliff overlooking the river three-quarters of a mile north-west of Ramsholt Church, but the section is now hidden by talus and overgrown. Mr. Charlesworth states that the Coralline Crag was 7 feet thick and was overlain by 4 feet of Red Crag,* but there seems to be no other published account of the section, though it has long been celebrated for the beauty of its fossils. Sowerby, about the year 1820, figured from this deposit, then newly-discovered, shells which had been sent to him by the Rev. G. R. Leathes, and a number were also described in Wood's Monograph of the Crag Mollusca. Prof. Prestwich says that "many species were more abundant at Ramsholt than in any other locality, and were generally in a very fine state of preservation—the bivalves often with both valves. Among the commoner species were *Cardita senilis*, *Cyprina islandica*, *Pecten maximus*, *P. opercularis*, *Panopæa Faujasii*, *Astarte Burtini*, *A. gracilis*, *Trochus ziziphinus*, *T. conulus*, and the large *Balanus concavus*. The latter occurred in hundreds."†

The Sutton outlier, on rising ground south of Pettistree Hall, is only about a third of a mile across, but having been the principal place from which S. V. Wood made his magnificent collection, and being fully described and illustrated by Prof. Prestwich, it has become one of the best known localities in the Crag district. The pits are not now worked, and though good sections of the Coralline Crag and its junction with the Red Crag are still to be seen, it will be necessary to refer to Prof. Prestwich's paper for a full account of the deposit.

The Sutton quarries now open are two—one (F on Prestwich's map and sections) lies about 120 yards west-north-west of the Bullock-yard, and is close to the summit of the hill—the other (D of Prof. Prestwich) is the Bullock-yard Pit, on the east side of the hill, at a somewhat lower level. There was formerly another pit towards the south-western end of the outlier; but this

* *Phil. Mag.*, ser. 3, vol. vii. p. 84. (1835.)
† *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 118. (1871.)

was only opened to obtain phosphate, and as it did not prove remunerative, it was ploughed over. The following description of it is condensed from Prof. Prestwich's account.*

Commencing with the highest beds, in the old quarry on the top of the hill, we again meet with the rock-bed, seen at Orford and Sudbourn, but absent at Ramsholt. The section is as follows† :—

	Feet.
Surface soil	—
g. Dark ferruginous beds of Bryozoa, mostly in fragments, some entire, with a few shells in the same state. White soft calcareous veins descend through these beds from the top	11
f. Fine sand and grit, comminuted shells, numerous small perfect shells, and some Bryozoa	6
e. Uniform fine compact sand, with small shells and Bryozoa in the position of growth	4
	21

The Bullock-yard Pit at Sutton is the one from which Wood collected so largely, and from which he obtained nearly every species of mollusc known from the Coralline Crag. Here the Coralline Crag, cut to a vertical cliff, against which the Red Crag abuts, is still well exposed. Its upper part shows sand full of comminuted shells (referred by Prof. Prestwich to the base of his division *f*); the lower part (Prof. Prestwich's bed *e*) consists of calcareous sand with upright Bryozoa and abundance of small perfect shells. A few *Lutrariæ* in the position of life were seen, but most of the other shells were single valves; though unworn a large number were angularly broken—perhaps by skates or cat-fish. Phosphatic nodules are scattered throughout, though not abundantly. According to Prof. Prestwich the London Clay was found in this pit 20 feet above high tide of the river Deben, but the junction is not now visible.

The third section of the Coralline Crag was an old pit, opened to obtain phosphate, towards the south-west end of the Coralline Crag outlier. It is now filled up, but Prof. Prestwich describes it as follows :—

	Feet.
Surface soil	1
d. White marly sands with seams of *Cyprina*	
c. Ditto with *Mya* and Bryozoa in lower part, and *Cardita*, *Astarte*, *Anomia*, and *Venus* common in upper part	17
b. Bed of comminuted shells, with single valves of *Cyprina*, *Pecten*, *Celiepora cæspitosa*, &c.	4
a. Bed of phosphatic nodules, with mammalian and cetacean remains, and foreign boulders	1
London Clay.	

* The bone-bed has been described in the last Chapter; the eroded surface of Coralline Crag under the Red Crag will be described in Chapter VI.

† *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 119. (1871.)

At this spot the surface of the London Clay lies only 8 feet above the level of the Deben, and Prof. Prestwich considers that a lower zone of Coralline Crag exists here than is represented in the Bullock-yard Pit.

On the opposite side of the river Deben, at the large coprolite-working north-east of Waldringfield Church, Mr. Stollery, the foreman, told Mr. Whitaker that, in places, some 6 inches of Coralline Crag had been got beneath the nodule bed of the Red Crag.

At Trimley, about five miles south-south-west of the Sutton outlier, as already mentioned, Coralline Crag is said to have been observed in the digging of a ditch.* The exact locality is not mentioned, and no trace of an outlier was observed during the progress of the Geological Survey of the district. Altogether the evidence seems insufficient to prove the occurrence of Coralline Crag here, and the bed may possibly be merely a light-coloured unoxidized portion of the Red Crag, or even a derivative boulder from the older deposit.

The only outlier of Coralline Crag that remains to be described is found at Tattingstone Hall, 4½ miles south-south-west from Ipswich and nearly 10 miles from the nearest of the other sections; but the pits opened in it are now overgrown. Mr. Charlesworth,† in 1835, speaks of the Coralline Crag as exposed for about 70 yards. Its thickness was 6 feet, and in attempting to dig through it work was stopped by the appearance of water at the further depth of 2 feet. Lyell,‡ writing in 1839, says that he "caused a pit about 7 feet deep to be sunk in the yard at Tattingstone Hall Farm, piercing the lowest part there exposed of the Coralline Crag, through green marls, with intervening layers of flaggy limestone, two or three inches thick. At the bottom of this pit I found marl of the same character, containing a large *Nucula*, *Venus ovata*, and some other shells; when the workmen were stopped by the quantity of water which flowed in. One of the flaggy beds of limestone was almost of a brick-red colour, and consisted chiefly of comminuted shells, like the green marl." Mr. Whitaker§ saw the Coralline Crag in 1877, and describes it as "evenly bedded, firm, made up of finely broken shells, mostly buff, hardened into stony lumps in discontinuous layers; about 5 feet, but has been deeper." He also speaks of the outcrop as "little more than a quarter of a mile along the bottom of the valley from north to south, and only an eighth of a mile wide at most. It is bounded westward by the narrow alluvium, on the other side of which London Clay crops out, and elsewhere by Red Crag, which comes on above, and the underground extent of the older Crag is probably small." Prof. Prestwich's illustration of the

* *Ann. Nat. Hist.*, ser. 3, vol. xiii. p. 203. 1864. The observation was, I believe, inserted by S. V. Wood, jun., on the authority of Mr. Acton.

† *Phil. Mag.*, ser. 3, vol. vii. p. 84. (1835.)

‡ *Mag. Nat. Hist.*, ser. 2, vol. iii. pp. 314, 315. (1839.)

§ Ipswich, Hadleigh, and Felixstow(*Memoirs of the Geol. Survey*), p. 27. (1885.)

buried cliff of Coralline Crag at Tattingstone will be found in the Chapter on the Red Crag (p. 89).

This completes the description of the sections which have been or are now visible of the Coralline Crag. It will be seen that the deposit consists essentially of calcareous sand, mainly composed of shells or Bryozoa; the upper portion having been cemented into soft limestone of similar origin, but having the aragonite fossils dissolved and the carbonate of lime re-deposited in the form of a cement, or as streaks of tufa. A few thin seams of marl, pale-green when wet but drying nearly white, have been found, but most of the so-called marl is merely wet calcareous sand. When a portion of the Coralline Crag is treated with acid, the calcareous constituents are entirely dissolved, and a small but variable residue is left composed of fine siliceous sand full of grains of glauconite, exactly like the Diestian sands of Antwerp.

A few phosphatic nodules, unlike those of the bone-beds and apparently formed in place, occur scattered through the Coralline Crag. Otherwise the lower portion seems to be in the condition in which it was laid down on the floor of the sea as a loose sand, or as a soft rock sufficiently consolidated to support branching Bryozoa and Corals. The contemporaneous consolidation of the sea-bed does not appear to take place in our latitudes at the present day; but in warmer seas it is common, and on the shores of the Gulf of Lyons I have picked up slabs of sub-littoral sands which had evidently consolidated quite recently in shallow water, and had been torn up by some storm.

The whole of the Coralline Crag is more or less current-bedded, sometimes at high angles, such as may be seen in an ordinary sandstone, sometimes in flowing curves. I have been unable to recognize in Prof. Prestwich's division *e* a single stratum unaffected by this current-bedding, for at Broom Hill—one of the two localities given for this horizon—the sketch (Fig. 4, p. 30) shows this structure distinctly throughout. I therefore spent a good deal of time in getting the exact inclination of the current-bedding in the Broom Hill Pit, for if this stratum had been laid down at a depth beyond the reach of currents, it would betoken deeper water than any other part of the formation; all the rest of the Coralline Crag is unmistakably false-bedded. The other locality where Prof. Prestwich considers horizontally stratified Crag to be present is at Sutton; but here, though the currents seem to have been gentle, it is interesting to note how constantly the straight cylindrical branches of *Salicornaria* have been rolled and waterworn. The rolled condition of small cylindrical Bryozoa and the unworn state of the ramose or heavier forms affords a good indication of the strength of the marine current, for it shows that the force must have been sufficient to move the smaller particles or sand, except where these happened to be immediately cemented by carbonate of lime, or bound together by organic growth. This contemporaneous binding together of the particles is, I believe, the cause of the occasional local absence of current-bedding and of the undisturbed state of the fossils—the currents

were there, but the Bryozoa had grown on a firm base and could not be detached. The evidence of the Bryozoa themselves is found to point in the same direction; for an abundant Bryozoan fauna, such as we find in the Coralline Crag, can only flourish in strong currents, and where the water is clear.

The fauna of the Coralline Crag is so rich as to afford abundant evidence for deciding under what conditions the beds were formed, and for making a comparison with other deposits. One peculiarity of the deposit, however, must not be lost sight of; calcareous strata of this character are exceptional among the European Pliocene groups, and it is not easy to find anything closely similar in the present seas of Europe. Such unusual conditions of deposit as those in which these calcareous formations were accumulated must, of course, encourage the growth of certain forms of life, but act inimically on others, and it is necessary to make allowance for this effect when we compare the fauna of the Coralline Crag with the fauna of strata of the Diestian type, or with that of the clayey deposits of St. Erth.

Taking the different classes of fossils in the order of their relative importance in the formation, the first place must be given to the Mollusca, though in many parts of the Coralline Crag Bryozoa are at least equally abundant. The number of species of mollusca recognised by Wood as belonging to the Coralline Crag amounted in 1882 to 420, of which he considered that 251, or 60 per cent., are still living. Jeffreys, on the other hand, in 1871 made the total 316, of which 84 per cent. belong to recent forms. Even if we leave out of account the rare extinct species described by Wood after Jeffreys published his criticisms, the discrepancy is still nearly as great, though both workers were using practically the same material—the Wood collection in the British Museum. This extraordinary difference is doubtless due, on the one hand, to the tendency of Jeffreys to refer characteristic fossil forms to living species, and on the other hand, to Wood's habit of considering any well-marked and constant variation in a Crag fossil from its nearest living allies to be sufficient to constitute it a new species. It is the old question—What is a species?—for there is seldom any discrepancy between these two authors as to the close alliance of the recent and fossil mollusca identified by the one but kept apart by the other.

The discordance in the percentage of extinct forms in the Coralline Crag when the mollusca are examined by different conchologists, shows to what an extent the "personal equation" comes into play, and how dangerous is the use of the per-centage test for correlating different deposits, unless where all the fossils have been determined by the same person.

In preparing this Memoir, and especially while studying the unknown fauna of Lenham, it has been necessary to make use of a number of monographs on French, Belgian, German, and Italian Pliocene mollusca, and it has seemed to the present writer that, comparing these monographs with the work of Wood, there is an equal or even greater tendency in most of the authors to accept

small differences as of specific value. Of course if this is the case, it would only cause confusion to treat the English Pliocene mollusca in a way that none of the continental palæontologists seem inclined to adopt for their Pliocene faunas. Any such revision would render it even more difficult than at present to compare the deposits, and the change would lead to no useful result. The "Crag Mollusca" has therefore here been adopted as the standard authority, and Wood's determinations have only been departed from in cases where there is a general concurrence of opinion against him, or where further evidence has shown that errors have been made.

It has long been known that a large proportion of the Coralline Crag mollusca are of Mediterranean or southern type, and Wood in 1874 analysed the list thus :—

British and not Mediterranean -	- 20
British and Mediterranean -	- 154
Mediterranean and not British -	- 51
Neither British nor Mediterranean	- 24
Not known living - - -	- 142
Total -	- 391

A considerable proportion of the extinct forms, and also of the living species that are neither British nor Mediterranean, are allied to southern molluscs (see Plates II. and III.) or are found in Miocene beds. One species only, according to Wood, is exclusively Arctic, and in this case he considers the determination somewhat doubtful. Jeffreys considers that several more of the Coralline Crag shells are Arctic.

However, we may put on one side these critical species, for it is evident that a study of the general character of the fauna will yield more satisfactory results. The statistical method also leads to the absurd position that a certain number of critical species, which according to the authority we follow, may be northern, southern, or extinct, are considered of equal value with a like number of southern species, belonging often to genera now unrepresented in northern seas. Among the genera which give such a southern character to the Coralline Crag fauna are large showy species of *Voluta, Cassidaria, Cassis, Ficula, Hinnites, Chama, Cardita,* and *Pholadomya.* Equally characteristic are the smaller *Ovula, Mitra, Triton, Vermetus, Ringicula, Verticordia, Coralliophaga,* and *Solecurtus.* These do not all belong to recent species, but even when the species is extinct, it can generally be found in south European Miocene or Pliocene beds, associated with a fauna still more southern than that of the Coralline Crag. Wood has also pointed out that "the most abundant and therefore most characteristic species of the Coralline Crag, such as *Cardita corbis, Cardita senilis, Limopsis pygmæa, Ringicula buccinea,* and others, are southern species unknown to British seas, and that among the 154 Coralline Crag species occurring both in British and Mediterranean waters there are many

which are really characteristic Mediterranean shells, and are only marked as British in consequence of some rare occurrence."

The Mollusca are such as flourish in the lower part of the laminarian and the upper part of the coralline zone. A small number of deep-water or littoral species are found, but individually they are not abundant, and they are also quite insufficient at any one spot to modify our impression of the general shoal-water character of the fauna. The average depth at which the living species of Coralline Crag Mollusca now flourish, if we take only those of which the identification is not in dispute, is about 45 or 50 fathoms, and we may safely calculate the depth at which this deposit was laid down to have been somewhere between 40 and 60 fathoms. A greater depth would not have produced the abundant *Rissoæ*, a less depth would encourage a larger proportion of littoral and plant-eating species.

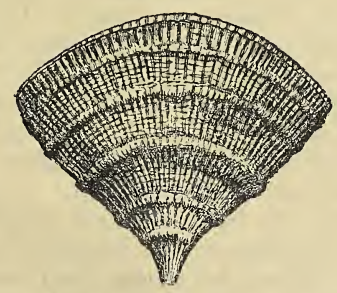
Next in importance to the Mollusca come the Bryozoa, which occur in such profusion as seems to be quite unequalled in any other deposit in Britain, or probably in Europe. Busk described 118 species, of which 76, or about 64 per cent., appear to be extinct. Among the extinct forms are the peculiar genera *Alveolaria* and *Fascicularia* (Fig. 3, p. 20), large massive bryozoa, characteristic of European Pliocene and Miocene deposits, and unlike anything now living. The living species among the Coralline Crag bryozoa have principally a southern distribution; a few are exclusively southern. But the species in this class have generally such a wide range, both horizontally and vertically, that they cannot be said to point to any very definite conclusions as to climatic conditions, or as to depth of water. The average depth from which the living Coralline Crag forms have been dredged appears to be about 65 fathoms, but a large proportion of them range from low-water mark to 160 fathoms. The essential conditions for bryozoa seem to be clear water and fairly strong currents. Depth or temperature are apparently of less importance, and may vary considerably without much affecting the character of the bryozoan fauna.

True Corals are only represented by three species, all of which

Fig. 5.

Flabellum Woodii, E. & H.

Natural size.



Milne-Edwards considered to be extinct. Two of them, *Sphenotrochus intermedius* and *Flabellum Woodii* (Fig. 5), are solitary

forms, belonging to southern genera; the third, *Cryptangia Woodii*, is a branching form always encrusted with *Cellepora*. The *Flabellum* is rare, the others are fairly abundant.

The Echinodermata amount to about 16 species, only three of which are still living. The genera point to warm seas, but nothing more definite can be said about them. *Temnechinus excavatus* (Fig. 6), *Amphidetus* (spines), and a species of *Brissus* are common; all the others are rare. This class is also represented in the Coralline Crag by three species of *Comatula*.

Fig. 6.

Temnechinus excavatus, S. Wood.

Natural size.

The Hydrozoa are peculiar and abundant, though only belonging to two species of *Hydractinia*. *H. circumvestiens* will be constantly met with, and is very likely to be mistaken for a *Cellepora*. It overgrows spiral univalves, generally *Trophon alveolatus* (see Fig. 7). *Cellepora edax*, on the other hand, usually incrusts small shells, especially *Natica* and *Turritella*. It gradually eats away the shell, so that in most specimens the walls have entirely disappeared, and what is found is a mass of *Cellepora*, with a spiral cavity retaining the impress of the external shape of its host.

Fig. 7.

Hydractinia circumvestiens, S. Wood.

Natural size.

Of Cirripedes, Darwin described 10 species, 4 of them extinct. The most conspicuous is the *Balanus tintinabulum*, a large species of barnacle, which often occurs in clusters of considerable size. It and the other living forms belong principally to warmer seas than ours. The rest of the Crustacea call for little remark. Prof. T. R. Jones records 19 species of Entomostraca, mostly belonging to the genus *Cythere*, and all except one are extinct. Few of the higher Crustacea of the period are known, but Prof. Prestwich mentions six species determined by Dr. H. Woodward; they are living forms.

Scattered bones and teeth of fish are often met with, the most abundant remains being gadoid otoliths. Teeth or dermal spines of the Skate and Wolf Fish occur, and the broken state in which so many of the mollusca are found, is probably largely due to the presence of these shell-eating fish. An extinct species of Tunny (*Thynnus scaldiensis*) has also been found.

Only one Bird has yet been recorded, but this is the ocean-loving albatross. Contemporaneous Mammals are represented by one of the larger Dolphins, for though land species occur in the nodule bed, none have yet been found higher up, away from the

mixture of derivative fossils. Two or three drifted land shells are the sole evidence of the proximity of land.

The nature of the deposits and the character of the fauna both point to the Coralline Crag as having originated as a sandbank far from shore in a warm, moderately shallow sea. It is very difficult to match it exactly at the present day; none of our English dredgings correspond very closely. Mediterranean dredgings are often more similar, though I have been unable to find any records of a Bryozoan deposit such as this. The conditions seem more like those we find among the Azores or off the coast of Portugal, where the current of the Gulf Stream and the Atlantic waves must keep the clear warm water in constant movement to a considerable depth, and so encourage the growth of Bryozoa. Off Portugal, however, the water deepens rapidly, and there is no wide submarine plateau, such as seems to have existed during the Older Pliocene period in our latitudes, owing to the submergence of a considerable part of the continental area.

CHAPTER IV.

LENHAM BEDS (DIESTIAN).

Besides the calcareous rocks described in the last chapter we have other representatives of the Older Pliocene series, corresponding in lithological character with those found on the opposite side of the North Sea, especially around Antwerp and Diest. These Deposits of "Diestian" type consist of fine glauconitic greensands, which are often changed, by the oxidation of their glauconite, into rusty sands, or become compacted into masses of ironstone. The sands are poorly represented in this country, but are of great interest; for they point to different conditions from those indicated by the Coralline Crag, and yield a somewhat different fauna from that contained in the latter deposit. Sands of this type are confined to the county of Kent. About nine miles east of Maidstone, at the foot of the North Downs, lies the village of Lenham. Behind the village the Down rises rapidly to a height of over 600 feet, and forms a long escarpment ranging in the one direction to Maidstone, in the other to Folkestone. It is on the edge of this escarpment that the sands and fossiliferous ironstone now to be described are found.

The first discovery of the outliers at Lenham seems to have been made in 1854 by Prof. T. R. Jones and William Harris, who spoke of them as belonging to the "basement-bed" [of the London Clay]. However, a series of the specimens was sent to Prof. Prestwich, whose "first impression was rather in favour of such a conclusion. Still there were some fossils which did not belong to that period—there were *Lunulites*, a large *Terebratula*, a species of *Emarginula*, and some peculiar spines of *Echini*, such as I had never met with in our Lower Tertiary strata."

Prof. Prestwich was able to visit the sections himself in the following year, and was so struck with the resemblance of some of the fossils to Crag species that he asked Searles Wood to examine them.

Wood, though he inclined to the view that the deposit was of the age of the Coralline Crag, spoke with great caution, owing to the bad preservation of the specimens, and to the impossibility of satisfactorily determining any of them. He observed that "In the present case, I am afraid the most that can be said is, that there is a stronger resemblance in these fossils to the shells of the Crag than to those of any other formation, and what may also perhaps assist in the assignment is the apparent absence of any

decided species exclusively belonging to the Older Tertiaries." Further on he remarked that "still, if it be asked whether a perfect reliance can be placed upon any specimens as truly characteristic of the Crag period, I fear an answer must be given in the negative, although the general aspect of the fossils is certainly favourable to the assumption that they belonged to the Upper rather than to the Lower Tertiaries." And commenting on the list he added, "The accompanying list contains the names of those species to which they bear a very close resemblance. I give them as approximations only; and, although there is not one which without a doubt could be satisfactorily determined, I still think that, taken collectively, they are such as to justify a probable assignment to one of the Crag periods, and they appear to have been inhabitants principally of the Coralline zone."

Prof. Prestwich, commenting on Wood's note, speaks much more decidedly, for he writes: "I must confess to hold a stronger opinion on the subject than Mr. Wood, for there are collateral circumstances which greatly strengthen my belief of these beds belonging to the Crag, little as I was prepared to meet with the Crag at such an elevation and such a distance from the main mass. In the first place, I know of no Eocene strata in the London Tertiary area quite like this deposit in its lithological structure . . . . . And fourthly, because I find similar beds on the chalk-downs on the opposite side of the Channel, between Calais and Boulogne; and thence, passing across the plain of French Flanders, we again meet with analogous strata,—though more important and with more ironstone,—on the top of Cassell Hill, 515 feet above the sea, and *overlying the Calcaire grossier series.*"*

Owing to the unsatisfactory state of preservation of the specimens, and perhaps also to an accidental mixture of Eocene fossils from another locality, this discovery was afterwards generally discredited or ignored. Prof. Prestwich himself has, however, always maintained its accuracy, and several foreign geologists have supported him.

Lyell in 1865† treated the Lenham ironstones as a continuation of the similar sands at Diest, and classed them doubtfully as Upper Miocene; but in 1866, according to Mr. Whitaker, he had given up this view, and the deposits are entirely ignored in subsequent editions of his works.

In 1862 Mr. Whitaker was inclined to refer the sands to the Crag,‡ but in 1866,§ and 1872,‖ he thinks rather that they *may*

* Prestwich. On the Age of some Sands and Iron-Sandstones on the North Downs. With a Note on the Fossils; by S. V. Wood. *Quart. Journ. Geol. Soc.*, vol. xiv. pp. 322–335. (1858.)

† Elements of Geology, 6th Edit. pp. 223, 368.

‡ *Quart. Journ. Geol. Soc.*, vol. xviii. p. 273.

§ *Ibid.*, vol. xxii. pp. 430–433.

‖ The Geology of the London Basin (*Memoirs of the Geological Survey*), pp. 336–342, 601.

be referred to the Lower London Tertiaries. Mr. Bristow also was disposed to class the beds as Eocene.*

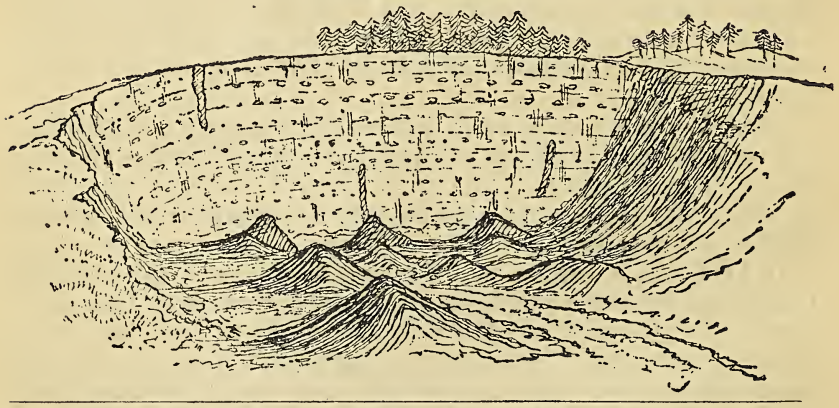
Prof. A. Von Koenen, after an examination of the specimens in the collections of Prof. Prestwich and of the Geological Survey, was of opinion that the fossils were of Pliocene age,† in which view he seems to have been supported by S. P. Woodward.

Messrs. Cogels and Van Ertborn, who have made a special study of the Antwerp Crag, in 1882 expressed the opinion that the Lenham ironstone was of Diestian age.‡ At that time I did not feel prepared to agree with them, having only been able to examine badly preserved fossils, and having also found in the Survey collection a piece of ironstone containing undoubted Eocene species. How it happened that this Eocene ironstone came to be mixed with the material from Lenham I am unable to learn, but apparently it has been placed in the same tray to show the lithological resemblance of the two beds, and not being labelled, has afterwards been taken to belong to the same series. Subsequent research at Lenham has not yielded a single Eocene fossil.

As the age of the deposits still seemed very uncertain, it was necessary for the purpose of this Memoir to re-examine the ironstones capping the Downs between Folkestone and Maidstone. The result of this examination was thoroughly to confirm Prof. Prestwich's view of the Pliocene age of the beds near Lenham ;§ but it does not necessarily follow that all the outliers similarly placed on the escarpment of the Downs are of the same age. The undoubtedly Pliocene sands of Lenham and Harrtetsham will therefore be described first. Afterwards the more doubtful deposits extending eastward and westward will be noticed.

Fig. 8.

Chalk-pit at Lenham.



* *Quart. Journ. Geol. Soc.*, vol. xxii. p. 553. (1866.)

† On the Belgian Tertiaries. *Geol. Mag.*, vol. iv. p. 501. (1867.)

‡ Note sur les sables ferrugineux des Downs du Nord. *Bull. Soc. Malacolog. Belg.*, vol. xvii. pp. 43–45.

§ The Pliocene Deposits of North-Western Europe (C. Reid). *Nature* vol. xxxiv. p. 341. (1886.)

The principal place where Pliocene fossils have been obtained is in a large Chalk pit half-a-mile north of Lenham. A sketch (Fig. 8) made in 1886 will explain better than words the mode of occurrence of the ironstone at this spot. In the distance clumps of fir occupy the crest of the escarpment at a height of about 630 feet. A few feet lower, and touching the 600-foot contour-line, is the edge of the pit, which has been cut out of the face of the escarpment, here not very steep. To the left the ground falls towards a small lateral valley, in which another chalk pit is situated. To the right the pit was much obscured by talus at the time of making this sketch, but it has since been again worked.

The Down above the pit is occupied by extensive sheets of clay-with-flints, underneath which occur patches of sand, clay, and fossiliferous ironstone. Beneath this superficial covering the Chalk is undergoing a constant process of solution, especially near the escarpment, where the beds are somewhat fissured and the water-level lies a long way down.

The result of this solution is to enlarge pre-existing fissures until they expand into more or less cylindrical pipes. Then as the Chalk disappears the overlying insoluble matter quietly subsides, often so regularly that the original succession of the beds can still be made out, though individual hard layers have been shattered and pulled apart. These "pipes" in the Chalk are well known to geologists, but as single pipes are seldom followed to any great depth it is perhaps scarcely realized to what a distance they may descend. Indeed the only limit to their depth seems to be at the plain of saturation, or at some impervious bed.

Turning again to our Lenham pit we see here and there on the face of the Chalk vertical black cylinders of clay and sand. These cannot often be seen stretching from top to bottom of the pit, for a mass of loose material like this is far too dangerous to be left to support its own weight. They are therefore generally cleared away in the upper part before they are broken into below. However, by watching one of these pipes for several successive years, or by talking with the quarrymen, one learns that every one of them continues upwards till cut off by the soil or by the clay-with-flints, and continues downwards beneath the floor of the pit.

In the foreground of the sketch are numerous black mounds. These are relics of pillars of clay left by the quarrying away of the Chalk around the pipes, these pipes being disturbed as little as possible, for the material filling them is quite valueless. The mounds used to form a conspicuous feature in this pit, and were especially noticeable when the sketch was made. Since that time they have been systematically pulled to pieces to obtain the masses of fossiliferous ironstone examined by the Geological Survey.

The contents of these pipes generally consist of an external shiny slickensided layer of black clay coating the wall of Chalk, and an internal confused mass of unworn flints, clay, and ferruginous or glauconitic sand, sometimes mixed with lumps of fossiliferous ironstone or ferruginous sandstone.

With the large unworn flints we have at present nothing to do. As a rule they are only the insoluble residue left during the formation of the pipes, or let down from the superficial clay-with-flints. It is probable that a good deal of the clay also belongs to this category.

Turning now to the sand and ferruginous sandstone, the material does not at first sight look very promising—to a superficial examination it is nothing but a rusty sand of somewhat finer grain than is usually found in the Drift. However, the sand in some of the pipes shows a greenish tinge, and if a number of the larger blocks of ironstone be broken up, one or two of them will probably yield traces of the material in something more nearly approaching to its original state. The sand is then loose and very glauconitic, though even in the least altered specimens it is still somewhat rusty and has been entirely decalcified.

Returning to Lenham on a second visit, after studying the Pliocene beds at Antwerp, I was much struck with the similarity of the deposits. We find the same fine sand full of glauconite,* and also the same tendency to oxidize into masses of ironstone with casts of fossils, like those which M. Van den Broeck had shown me near Diest.

In the pit just described the depth to which the material has subsided through the pipes is so great—probably not less than 80 feet—as quite to obliterate any trace of the order of succession. However, a certain number of the blocks of ironstone evidently belong to the bed that rested directly on the Chalk, for besides the Pliocene fossils they contain unworn flints and derivative fragments of *Inoceramus* and spines of *Cidaris clavigera*. Of derivative Eocene fossils not a trace has yet been observed, though the scattered pebbles of flint may possibly be a relic of one of the older pebble beds. Small pebbles of quartz are also occasionally found.

This pit is not quite at the highest point on the Lenham Downs, though very near it. A search soon showed, however, that the same fossiliferous ironstones cap the highest part of the hill, for a cast of *Terebratula grandis* was found in a pipe in the road-cutting near Lee Farm, a quarter of a mile to the north-west. This was at a height of about 620 feet, 680 feet being the highest point within several miles. About 60 yards higher up the road bright red or mottled loamy micaceous clay is exposed by the road-side, but it is thin and is immediately hidden by the clay-with-flints. Similar red clay is seen in the road north-north-west of Lee Farm at about the same level.

Unfortunately there are so few pits away from the escarpment, and the dip slope is so obscured by clay-with-flints, that little can be said about the succession or nature of the deposits where undisturbed.

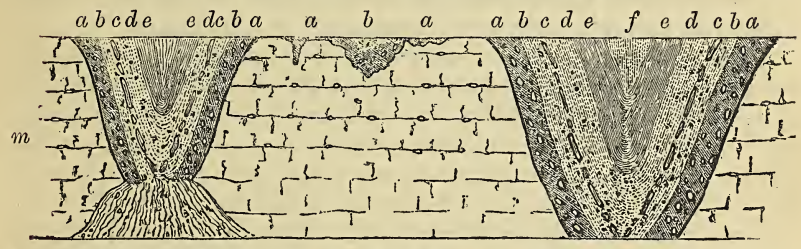
A quarter of a mile west-north-west of Marlow Farm there is another exposure, placed a short distance down the escarpment

* Glauconite is a silicate of ferric oxide, potash, and alumina, but varies much in composition and specific gravity, and is probably always mixed with impurities.

on the 600-foot contour. This is the pit described by Prof. Prestwich, whose sketch (Fig. 9) has been borrowed, for the section is now too much overgrown to allow of a proper examination.* Prof. Prestwich could only find a few traces of fossils at this locality, though he mentions the cast of a *Cardium* as having been found after his visit. I could only meet with a single indeterminable fragment.

Fig. 9.

Section on the Hill above Harrietsham, Kent.

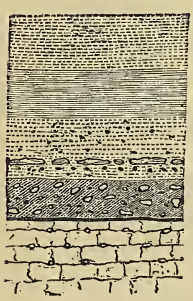


f, *e*. Fine light-red and yellow sands, in parts very argillaceous.
d–*b*. Greenish sand, more or less argillaceous, with a subordinate bed or seam of ironstone concretions (*c*). In places *c* reposes directly on *a*.
a. Unrolled chalk-flints in brown and black clay. *m*. Chalk.

In the above figure it will be seen that the subsidence of the beds into the pipes has not been sufficient to obliterate the original succession, and in a diagram section (Fig. 10) Prof. Prestwich

Fig. 10.

Diagram-section of the Iron-sands in their original horizontal position.



f. Yellow sands, passing down into

e. Light red sand and clay.

d. } Greenish and yellow sands, with a subordinate
c. } seam of ironstone, *c*, and some flint-pebbles.
b. }

a. Chalk-flints in Clay.

m. Chalk.

replaces the layers in a horizontal position, so as to show the original order of the deposits. To this reconstruction no objection can be made, except that probably the bed of "Chalk-flints in Clay" (*a*) ought not to be placed underneath the undisturbed Pliocene Beds. It is evident that the solution of the mass of Chalk which formerly occupied the two pipes shown in Fig. 9 would leave a considerable mass of insoluble flints, together with

* Figs 9 and 10 are borrowed, by permission of the Council of the Geological Society, from *Quart. Journ. Geol. Soc.*, vol. xiv., pp. 326, 327. (1858.)

the finer particles of the clay which with every movement would tend to work their way downward to the base of the coarser beds, where, arrested by the closer-grained Chalk, they would be, as it were, filtered out. The Lenham section also seems to show that the true basement bed of the Pliocene deposit is sandy, not clayey.

Another old pit, due north of Harrietsham and a quarter of a mile north-west of Dean's Hill, shows two pipes with lumps of ironstone, some containing flint pebbles others partially weathered glauconite. The ironstone is only sparingly fossiliferous. This pit is on the 500-foot contour, but the escarpment rises to 627 feet within 200 yards, and it is evident that the ironstone must have travelled down the pipes from about that height.

East of Lenham there occurs another Chalk pit, at about a mile from the village and close to the Pilgrim's Road. This pit is at a height of about 550 feet. It shows pipes of red micaceous sand, with occasional fragments of fossiliferous ironstone. The sand contains a few grains of unweathered glauconite. Close to this pit is the highest point in the neighbourhood—680 feet.

Nearly 2 miles east-north-east of Lenham, in a chalk-hole now filled up, in the field west of Warren Street, Prof. Prestwich found the following small section remaining, of strata which are *in situ* :—

	Ft.	In.
Yellow sand - - - - - -	1	0
Mixed red clay and yellow sand - - -	3	0
Seam of compact ironstone, with traces of fossils -	0	2
Layer of small flint-pebbles - - - -	0	6
Brown sand and clay - - - - -	1	0

The height of this section is nearly 620 feet above the sea.

Above the village of Charing the fossiliferous ironstones have again been met with, for Mr. Harris records (*fide* Prof. Prestwich) that at the depth of 6 feet was "found a continuous stratum of fossiliferous iron-sandstone reposing on a bed of very large chalk-flints, externally stained with iron, and a few pieces of iron-sandstone. The sandstone was from 4 to 6 inches in thickness." This pit also appears to be about 620 feet above the sea.

This completes the record of the fossiliferous sections, and also of the sections where the beds are sufficiently well preserved to retain their original glauconitic character. The whole of these exposures occur on the edge of the escarpment above Harrietsham, Lenham, and Charing, in a distance of about 7 miles.

Turning next to the similarly placed unfossiliferous outliers, it is at present impossible to say definitely whether they are of Pliocene or of Eocene age. The following notes must therefore be taken merely as describing such deposits as will probably, or may possibly, prove to be a continuation of the Diestian, not as now claiming them to be undoubted Pliocene strata.

Westward towards Merstham and Guildford some of the outliers mapped by the Survey as Eocene may really be Pliocene, as suggested by Prof. Prestwich, but at present there is such an

entire absence of positive evidence in favour of this view, that it is needless to describe them.*

Eastward one finds a long belt of outliers of ferruginous sands near the Chalk escarpment between the river Stour and Folkestone. These have been coloured by the Survey as Eocene, but they are widely separated from the undoubted Eocene of the London Basin. Their resemblance to the Lenham beds is so great, that now that the latter have been proved to be of Pliocene age, it will probably be necessary to follow Prof. Prestwich in referring them also to the Upper Tertiary series. At present, since only one or two indeterminable fossils have been found, we are obliged to confine ourselves to the stratigraphical and lithological evidence.

One of the chief masses of these sands is at Paddlesworth, at a height of from 560 to 600 feet above the sea. These strata "there form a slightly detached hill, and consist of 30 to 40 feet of ochreous and ferruginous sands, more or less argillaceous, with subordinate fine quartzose grits and broken beds and seams of iron-sandstone,—some of these forming blocks of three to four feet wide by one foot thick, or even more. These blocks, which are common in and about the hamlet, sometimes contain flint-pebbles and unrolled flints. The fields in the neighbourhood are strewed over with fragments of ironstone, and in a few of these I found on one occasion pieces of fossil wood pierced by the *Teredo*, together with that which appeared to be the cast of a bivalve shell. Yet on the neighbouring shore at Folkestone, which is covered at places with blocks fallen from the top of the cliffs, and presenting therefore very favorable opportunities for examination, I have not found a single fossil."† Mr. Topley who mapped these beds, found a cast of a large bivalve (*Cyprina*) in this neighbourhood. "At the northern end of the patch, between Mudshole and Uphill, west of Hawkinge," he "saw a pipe of red and yellow sand, about 4 feet thick, with an inch layer of white pipeclay. The red sand weathers pink. Another chalk-pit, just west, shows 4 or 5 feet of sand and iron sandstone with 3 or 4 inches of white and mottled pipeclay, passing into mottled clayey sand. There are pieces of sandstone in this pit."‡

On the Chalk ridge above Folkestone there is a large mass of sand, the irregular junction of which with the Chalk may be seen along the top of the high cliff, where there is much iron-sandstone. "The highest ground is near Upper Coldham, and there the sand ends off with a marked feature and would seem to be 50 or 60 feet thick. Sand and iron-sandstone may be well seen in the railway-cutting just east of the Folkestone tunnel, in the fallen masses of the Undercliff."§

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* Full details will be found in Mr. Whitaker's Geology of the London Basin. (*Memoirs of the Geological Survey*), vol. iv. pp. 339–342. (1872.)

† Prestwich, *op. cit.* p. 324.

‡ From Mr. Topley's notes in Geology of the London Basin (*Memoirs of the Geological Survey*), p. 342. (1872.)

§ From Mr. Topley's notes, *op. cit.* p. 342.

At Folkestone and Paddlesworth, where little or no trace of glauconite occurs, and where the whole deposit seems much more weathered than at Lenham, a few quartz pebbles may still be noticed, mixed with the flints towards the base of the sands. The way in which the beds lie somewhat irregularly on the Chalk, and do not follow the dip slope towards the north, but are almost confined to the edge of the escarpment, is suggestive of a marked unconformity, though this cannot at present be proved from actual sections.

On the further side of the Straits of Dover similar deposits cap the hills between Calais and Boulogne, generally at a height of from 400 to 500 feet. Inland they stretch eastward into Belgian Flanders, and form a continuous chain of outliers connecting the fossiliferous beds of Lenham with those of Diest.

In France no fossils have yet been found in these deposits, though on Cassel Hill, where they reach an elevation of 515 feet, they are of a very considerable thickness (about 45 feet) and have been carefully searched.

A few miles across the French frontier, in Belgian Flanders, M. Piret has lately discovered a cast of *Terebratula grandis*, at a place called Wevelghem, between Courtrai and Menin.* The specimen was not found in place, but there seems no reason to believe that it had been transported far.

Though palæontological evidence is not always forthcoming, the stratigraphical and lithological evidence of the former continuity of the beds seems clear. The gaps between the outliers which connect Diest and Lenham are unimportant, the largest being that occupied by the Straits of Dover. There appears now to be no reasonable doubt that we are dealing with a widespread sandy Diestian formation, which once covered great part of Holland, Belgium, northern France, and southern England, though denudation has since cut it into numerous outliers, often capping isolated hills.†

Still tracing the beds eastward one finds that beyond Brussels the ferruginous sands begin to form larger masses, till finally they unite into a wide sheet stretching from Louvain to Antwerp, and northward into Holland. At the same time the deposits change in lithological character and become less weathered as they sink beneath the sea level. Except the above-mentioned *Terebratula* from Wevelghem the first occurrence of determinable Diestian fossils is at Everbergh, about 10 miles east of Brussels, and from this point there is no doubt as to the continuity of the deposits.

In the summer of 1886 I had the great advantage of visiting the typical Diestian area in company with my friend Mr. Van den Broeck, who had recently mapped in detail great part of that

* Note sur un nouveau Gisement de la *Terebratula grandis*. . . . par E. Van den Broeck. *Mém. Soc. Belge Géol.*, vol. i. p. 49. (1887.)

† A good map of the distribution of the Pliocene deposits in Belgium will be found in M. Van den Broeck's paper. *Op. cit.* Pl. II.

district. He drew my attention to the strong unconformity which separates the Diestian beds from any of the older deposits. This break was noticeable in the Bolderberg, where the Diestian, with casts of its characteristic shells, rests irregularly on fine Miocene sand with a line of pebbles and silicified fossils having a totally different character. This disturbance of all the beds up to and including the Miocene, and their great denudation before the deposition of the oldest Pliocene, is an important point, and will be again alluded to.

When we leave the higher ground and descend towards the flat country near Antwerp, we find the beds to undergo a gradual change. In the neighbourhood of the city, where they underlie the later "Scaldisian" deposits, they have become quite unweathered. Instead of appearing in the form of ferruginous sandstone, they consist of soft sand full of glauconite, and containing abundance of well-preserved calcareous fossils. The difference in the lithological character of the deposits is so great, that it has only lately been clearly recognized that we are merely dealing with weathered and unweathered portions of the same bed. This has been principally proved by the researches of Messrs. Cogels, Van Ertborn, and Van den Broeck, who have shown that the casts found in the neighbourhood of Diest belong to the same species as the well-preserved shells found in Antwerp Docks.

A study of the changes produced by weathering also led to the discovery that the line accepted by the older writers as the junction of the Scaldisian with the underlying Diestian at Antwerp was merely a line of colour. The real junction is marked by a band of pebbles, across which the supposed boundary between the "black crag" and the upper lighter-coloured division passes diagonally. On visiting the new Antwerp Docks in company with Messrs. Cogels and Van Ertborn, I had the opportunity of examining the long sections there exposed. I found that these observers were undoubtedly right in their contention, and that in preparing lists of the faunas of the two deposits it becomes necessary to ignore the lists made before the true line of junction was recognized. In the older collections some of the Scaldisian species have probably been placed in the lower division; while on the other hand some of the Diestian species have wrongly been included in the later fauna, owing to their occurrence in a light-coloured matrix. Lithologically the Diestian and the Scaldisian sands are almost identical, there being no sharp change, as there is from our calcareous Coralline Crag to the overlying coarsely quartzose Red Crag.

Besides this cause of confusion, Miocene beds have been touched at the bottom of certain of the Docks at Antwerp. The Miocene shells have not always been clearly separated from the overlying Diestian, and it is possible that this mixture has helped to give rise to the belief in a passage between the Miocene and the Pliocene. In reality there appears to be nothing in Belgium approaching to a "Mio-Pliocene" formation. As in England,

there is a marked unconformity at the base of the Pliocene. In Belgium the most recent deposits found beneath the Pliocene are the Miocene beds known as Bolderian and Anversian.*

We have now traced the sandy, or Diestian, type of Lower Pliocene from Kent through northern France to Belgium, but it still remains to compare the faunas of the different districts. This may fairly be done, for lithologically the beds are similar; while the bathimetrical depths at which the shells lived seem to have been nearly the same, and the mollusca must also have inhabited closely adjoining portions of the same sea, with no barrier between them. Under these circumstances we have a right to expect a close resemblance between the faunas, if they are truly contemporaneous.

Before analyzing the lists it may be well to point out any slight local circumstances which may have modified the character of the fauna, and which should be allowed for when we compare the different areas. The shells found at Lenham come from a bed that lies almost directly upon the flinty Chalk. They include abundant *Arcadæ*, and numerous rock-loving gasteropods, mixed with the species commonly found in sand, but no truly littoral forms, no *Rissoæ*, and few herbivorous gasteropods of any sort, though the carnivorous species are abundant. The Chalk probably formed a bare submerged reef for part of the time. The depth of water over this reef must have been considerable, for most of the bivalves have their valves united, broken shells are rare, and worn specimens are unknown. Taking everything into consideration, I think we cannot place the depth of water at less than 40 fathoms.

In the area around Diest, where the sands rest on a great variety of beds, but the fauna is that found on a sandy bottom, there is no evidence that reefs of the older rocks were bare for a sufficient length of time to influence the character of the fauna. Though the beds around Diest occur at a considerably lower level than the top of the Downs near Lenham, they contain broken shells more abundantly, and the fauna has perhaps a somewhat more littoral facies.

At Antwerp the sand is replete with the fauna belonging to the deposit in which the shells are now found, without any mixture of rock-loving forms. Though the locality lies 600 feet lower than Lenham, the depth of water seems to have been about the same, perhaps slightly less.

In a deep well at Utrecht, Diestian beds were found to extend to a depth of at least 1,140 feet beneath the sea.† Yet the character of the fauna—as far as one can judge by the specimens

* See also P. Cogels, Considérations nouvelles sur les systèmes bolderien et diestien. *Ann. Soc. Malacol. de Belgique*, vol. xii. pp. 7–26, (1877,) and E. Van den Broeck, Découverte de Fossiles miocènes dans les Dépots de l'Étage Bolderien. *Ibid.*, vol. xix. pp. lxviii.–lxxv. (1884.)

† J. Lorié, Contributions à la Géologie des Pays-Bas. I. Résultats géologiques et paléontologiques des Forages de Puits à Utrecht, Goes et Gorkum. *Archives du Musée Teyler.* Ser. II., vol. ii., 3rd part. (1885.)

obtained from a boring—is very similar to that at Lenham, and the depth of water is no greater.

To assist comparison of the different localities and their faunas, a table has been drawn up showing the whole of the known species of mollusca and brachiopods from Older Pliocene beds of the Diestian type. The object of this list is to ascertain whether the faunas from the different localities are such as might be expected to inhabit adjoining portions of the same sea under similar conditions. It was necessary in preparing the table for this purpose to eliminate all exceptional deposits, and in the analysis only to deal with those fossils which may reasonably be expected to occur at all the localities. Mere numerical comparisons of the species common to two deposits formed under different conditions are quite useless for settling whether the beds are or are not contemporaneous. In fact they are worse than useless, they are misleading. No one expects to find the same fauna inhabiting all portions of the English Channel at the present day. The Coralline Crag and the St. Erth clays have purposely been omitted from the table, because they are of different lithological types and consequently contain a number of species that probably would not live on a bottom of ordinary quartz sand.

Diestian Fossils.

(All but those marked * occur also in the Coralline Crag.)

	Lenham.	Diest, &c.	Antwerp.	Utrecht, &c.
Actaeon subulata, *S. Wood*	..	..	×	
—— tornatilis, *L.*	×	..	×	
Adeorbis striatus, *Phil.*	..	..	×	
—— subcarinatus, *Mont.*	..	..	×	
Aporrhais, see Chenopus.				
Buccinopsis Dalei, *J. Sow.*	×	×	×	
Buccinum undatum, *L.*	..	..	..	×
Bulla acuminata, *Brug.*	..	..	×	
—— lignaria, *Linn.*	×	×	×	
Calyptræa chinensis, *L.*	?	×	..	×
Cancellaria contorta, *Bast.*	×			
—— Lajonkairi, *Nyst*	..	..	×	
Capulus ungaricus, *L.*	..	..	×	×
Cassidaria bicatenata, *J. Sow.*	..	..	×	
*Cassis saburon, *Brug.*	..	×		
Cerithium granosum, *S. Wood*	..	..	×	
—— tricinctum, *Broc.*	×			
—— tuberculare, *Mont.*	..	..	×	
Chemnitzia elegantissima, *Mont.*	..	..	×	
—— similis, *S. Wood*	..	..	×	
Chenopus pes-pelicani, *L.*	×	×	×	×
Clavatula, see Pleurotoma.				
*Conus Dujardini, *Desh.*	..	×		
Cylichna cylindracea, *Penn.*	..	×		
—— umbilicata, *Mont.*	..	..	×	
Cypræa europæa, *Mont.*	×	..	×	

	Lenham.	Diest, &c.	Antwerp.	Utrecht, &c.
Dentalium costatum, *J. Sow.*	?	×	×	
——— vulgare, *Da C.*	..	..	×	
Emarginula fissura, *L.*	×			
Eulima intermedia ? *Cantr.*	..	..	×	
——— subulata, *Don.*	?	..	×	
Ficula reticulata, *Lam.*	×	×	×	
Fissurella græca, *L.*	×			
Fossarus lineolatus, *S. Wood*	..	..	×	
Fusus gracilis, *Da C.*	..	×		
——— lamellosus, *Bors.*	×			
Margarita trochoidea, *S. Wood*	×			
Nassa labiosa, *J. Sow.*	..	×		
——— prismatica, *Broc.*	×			
*——— reticosa, *J. Sow.*	..	×		
Natica millepunctata, *Lam.*	×	×	..	×
——— varians ? *Duj.*	×	×	×	
——— cirriformis, *J. Sow.*	..	×	×	
——— Alderi, *Forbes*	..	..	..	×
——— helicina, *Broc.*	..	..	..	×
Odostomia conoidea, *Broc.*	..	..	×	
Pileopsis, see Capulus.				
*Pleurotoma consobrina, *Bell.*	×			
——— inermis, *Partsch*	..	×		
——— intorta, *Broc.* var. plicatilis	..	×		
——— modiola, *Jan.*	..	..	×	
*——— Jouanneti, *Desm.*, var.	×			
——— turrifera, *Nyst*	×	..	×	
*——— plicifera, *S. Wood*	..	..	×	
Purpura tetragona, *Sow.*	?			
Pyramidella plicosa, *Bronn*	..	..	×	
Pyrula, see Ficula.				
Ringicula buccinea, *Broc.*	..	×	×	
——— ventricosa, *J. Sow.*	×			
Rissoa proxima, *Alder*	..	..	×	
——— Stephanisi, *Jeff.*	..	..	×	
Scalaria clathratula, *Adams*	×	..	×	
——— frondicula, *S. Wood*	..	..	×	
*——— Hennei, *Nyst*	..	..	×	
——— subulata, *J. Sow.*	..	..	?	
Scaphander, see Bulla.				
*Terebra acuminata, *Bors.*	×			
——— inversa, *Nyst*	..	..	×	
Tornatella, see Actaeon.				
Triton heptagonum, *Broc.*	×			
*Trochus cinerarius, *L.*	×			
——— conulus, *L.*	..	..	?	
——— millegranus, *Phil.*	×			
——— obconicus ? *S. V. Wood*	..	?		
——— occidentalis, *Migh. & Ad.*	..	..	×	
——— turbinoides, *Nyst*	..	×	×	
——— ziziphinus, *L.*	×	×	×	
Trophon alveolatus, *J. Sow.*	..	×	×	
Turbonilla, see Chemnitzia.				
Turritella incrassata, *Sow.*	×	×	×	
Voluta Lamberti, *Sow.*	..	×	×	
*Xenophora, sp.	×	×		
Abra prismatica, *Mont.*	..	×	×	×
Anomia ephippium, *L.*	..	×	×	×
——— striata, *Broc.*	..	..	×	
*Arca diluvii, *Lam.*	×			

	Lenham.	Diest, &c.	Antwerp.	Utrecht, &c.
Arca lactea, *L.*	×	..	×	
—— pectunculoides, *Scac.*	..	..	×	
Artemis lentiformis, *Sow.*	×			
—— lincta, *Pult.*	..	..	×	
Astarte Basteroti, *Laj.*	×	×	×	
—— Burtini, *Laj.*	..	..	×	
*—— corbulöides, *Laj.*	..	×	×	×
—— Galeotti, *Nyst*	×	..	×	×
—— incerta, *S. Wood*	..	×	×	
—— mutabilis, *S. Wood*	..	..	..	×
—— Omalii, *Laj.*	×	×	×	×
—— pygmæa, *Münst.*	..	..	..	×
*—— sulcata, *Da C.*	..	×	?	
—— triangularis, *Mont.*	..	..	..	×
Avicula, sp.	×			
Cardita chamæformis, *Leathes*	..	×	×	×
—— corbis, *Phil.*	..	..	..	×
—— orbicularis, *Leathes*	..	×	×	×
—— scalaris, *Leathes*	..	×	×	×
—— senilis, *Lam.*	×	..	×	×
Cardium decorticatum, *S. Wood*	..	×	×	
—— edule, *L.*	..	..	..	×
—— fasciatum, *Mont.*	..	..	..	×
—— nodosum, *Turt.*	..	..	×	
*—— papillosum, *Poli*	×			
*—— n. sp. ?	×			
Circe minima, *Mont.*	..	..	×	
Corbula gibba, *Olivi*	.	×	×	×
Cryptodon flexuosum, *Turt.*	..	..	×	
Cucullæa, see Arca.				
Cultellus tenuis, *Phil.*	..	×	×	
Cyprina islandica, *L.*	×	×	×	×
—— rustica, *Sow.*	..	..	×	×
Cytherea chione, *L.*	×	×	×	
—— rudis, *Poli*	..	..	×	
Diplodonta astartea, *Nyst*	?	×		
—— rotundata, *Mont.*†	×	..	×	
Donax politus, *Poli*	..	×		
Ensis, see Solen.				
*Gastrana fragilis, *L.*	×			
Glycimeris angusta, *Nyst*	..	..	×	×
Hinnites crispus, *Broc.*	×			
Isocardia cor, *L.*	?	×	×	
Kellia ambigua, *Nyst & West.*	..	..	×	
—— suborbicularis, *Mont.*	..	..	×	
—— semistriata, *S. Wood*	?	×	×	
—— pygmæa, *Munst.*	..	..	×	
Lepton deltoideum, *S. Wood*	×			
—— depressum, *Nyst*	..	..	×	
Lima Loscombi, *Sow.*	?	×	×	
—— subauriculata, *Mont.*	..	..	×	×
Limopsis aurita, *Broc.*	..	×	×	
—— anomala, *d'Eichw.*	..	..	×	×
Lucina borealis, *L.*	..	×	×	×
Lutraria elliptica, *Lam.*	×	..	×	
Mactra arcuata, *Sow.*	×	×		
Modiola sericea, *Brown*	..	×	×	
—— phaseolina, *Phil.*	..	?	×	
Montacuta bidentata, *Mont.*	..	..	×	

† = dilatata, Wood = Woodi, Nyst.

	Lenham.	Diest, &c.	Antwerp.	Utrecht, &c.
Montacuta ferruginosa, *Mont.*	..	..	×	
Mya fragilis, *Nyst*	..	..	×	×
——— truncata, *L.*	..	..	×	
Mytilus edulis, *L.*	..	..	..	×
Neæra obesa, *Lovén*	..	..	×	
Nucinella ovalis, *S. Wood*	..	..	×	
*Nucula Cobboldiæ, *Sow.*	..	..	..	×
——— lævigata, *Sow.*	..	×	×	?
——— nucleus, *L.*	..	..	×	×
*——— sulcata, *Bronn*	×			
Ostrea Princeps, *S. Wood*	×	×	×	
Panopæa Faujasi, *Men. de la Gr.*	..	×	×	
Pecten Gerardi, *Nyst*	..	..	×	×
——— lineatus, *Da C.*	..	..	×	
——— maximus, *L.*†	×	?	×	
——— opercularis, *L.*	..	×	..	×
——— princeps, *Sow.*	×	..	×	
——— similis, *Laskey*	..	..	..	×
——— pusio, *L.*	..	?	?	
——— radians, *Nyst*	..	..	×	×
——— tigrinus, *L.*	..	×	×	
——— septemradiatus, *Mull.*	..	..	..	×
——— varius, *L.*	×			
*——— Westendorpi, *Nyst*	..	..	×	
*——— n. sp. ?	×			
*——— n. sp. ?	×			
Pectunculus glycimeris, *L.*	×	×	..	×
Pholadidea papyracea, *Turt.*	×			
Pinna pectinata, *L.*	..	..	×	
Poromya granulata, *Nyst & W.*	..	..	×	
Psammobia ferroënses, *Chemn.*	..	..	×	×
Saxicava rugosa, *L.*	..	×		
Scintilla compressa, *Phil.*	..	..	×	
Semele, see Abra.				
Solen ensis, *L.*	×	×	×	
Tapes, sp.	×			
Tellina balaustina, *L.*	..	..	×	
*——— Benedeni, *Nyst*	×	×	×	×
——— donacina, *L.*	×			
——— compressa, *Broc.*	..	..	×	×
Teredo, sp.	×	×	×	
Thracia inflata, *Sow.*	..	×		
——— pubescens, *Pult.*	×	..	..	×
——— ventricosa, *Phil.*	×			
Venus casina, *L.*	..	×	?	
——— imbricata, *Sow.*	..	×		
——— ovata, *Penn.*	..	×	×	×
Woodia digitaria, *L.*	..	..	×	×
——— excurrens, *S. Wood*	..	..	..	×
Yoldia, see Leda.				
Argiope cistellula, *S. Wood*	..	..	..	×
Terebratula grandis, *Blum.*	×	×	×	×
Lingula Dumortieri, *Nyst*	..	×	×	
Terebratulina caput-serpentis, *L.*	..	..	..	×

† = P. grandis, *Sow.*

The total number of species in the foregoing table is 189; of these all except 22 have also been found in the Coralline Crag. We may therefore unhesitatingly state that the Diestian deposits

and the Coralline Crag, if not absolutely contemporaneous, are so closely allied that it is impossible to refer them to different portions of the Pliocene period. Turning next to the 22 species still to be accounted for, 9 of the forms that are unknown in the Coralline Crag are still living; and 5 are extinct molluscs known to occur in Upper Pliocene beds. Against these we have to place 2 south European Pliocene and Miocene shells, *Arca diluvii* and *Terebra acuminata;* 3 generally considered to be characteristic Miocene fossils, *Conus Dujardini* (a common Belgian Miocene fossil, also found in the "box-stones" at the base of the Crag), *Pleurotoma consobrina* and *Pleurotoma Jouanneti* (both characteristic Italian Miocene fossils); and 3 species apparently new which are confined to Lenham. Thus the Diestian fauna includes 14 species which point to its being newer than the Coralline Crag, and 8 species which point to its being older. If, however, our acquaintance with the whole Miocene fauna were as extensive as with the recent mollusca, this small difference would probably disappear, for it is more probable that several additional Diestian forms will be discovered in Miocene beds, than that a corresponding number of supposed extinct shells will be found still to be living. The foregoing list, instead of showing that the Diestian sands belong to a Mio-Pliocene formation older than the Coralline Crag, as was formerly thought, points to its being slightly newer, but the difference is so extremely small that it may safely be ignored.

Leaving statistics—never very satisfactory when the relative age of closely allied deposits is to be inquired into—there are some slight changes in the distribution of the species as one travels from north-east to south-west which strongly suggest warmer seas in the latter direction. Probably even in Pliocene times the Gulf Stream warmed the western shores, and four degrees further west would then as now no doubt involve a distinct rise in the temperature of the water.

The Diestian beds of Holland have only been reached in borings, so that a comparatively small number of fossils has yet been obtained from them. These, however, have been carefully collected and described by Dr. Lorié, who kindly showed me the original specimens during my visit to Utrecht. The lower beds in the borings seem to have been correctly referred to the Diestian series, but one cannot help noticing that southern forms are decidedly rarer than they are at Lenham, at any rate in the number of individuals. One species, *Nucula Cobboldiæ*, is a northern mollusc unknown elsewhere in beds older than the upper part of the Red Crag, but occurring in profusion in Newer Pliocene and Older Pleistocene deposits. It is an extinct form, but its invariable association with boreal species in this country leaves no doubt that it was a truly northern mollusc. The oldest specimens at Utrecht seem to be dwarfed and small, as is often the case with boreal species towards their southern limit. Not one of the *southern* species belonging to the Diestian beds is confined to Holland or especially abundant there.

Quite recently another well has been bored further north, at Diemerbrug, near Amsterdam. This boring reached a depth of 1,096 feet without penetrating any deposits that could be referred with certainty to the Diestian. A fuller account of the boring will be found at p. 220, but owing to the doubt as to their exact horizon the fossils have not been incorporated in the tables in this volume.

The Belgian list includes two southern forms unknown in Britain. These are *Scalaria Hennei*, thought by Nyst perhaps to be referable to *S. delicatula* of the Canaries, and the *Conus*, which, though an extinct form, belongs to a decidedly southern genus; both these shells are rare. The cone, though unknown in place in Britain, has been found in the derivative "Box Stones" at the base of the Crag (see p. 13).

At Lenham the southern character of the fauna is much more noticeable; for though the list from that locality is considerably smaller than that from Belgium, it contains about a dozen southern species unknown in Belgium, and four of them are unknown in the Coralline Crag; besides which some of the Mediterranean forms rarely found in the Coralline Crag occur at Lenham in abundance. From Lenham about 67 species have now been determined. Among these we find such southern genera as *Ficula* (*Pyrula*), *Xenophora* (*Phorus*), *Triton*, and *Avicula*, while the profusion of *Arca diluvii* and *Cardium papillosum* helps to give a distinctly Mediterranean character to the fauna, borne out also by the extinct south European species of *Pleurotoma* and *Terebra* associated with them. The few fossils not belonging to the mollusca point in the same direction. The polyzoon *Cupularia canariensis* is often found, but now lives only in the warm seas of Madeira and the Canaries; another species, the extinct *Fascicularia aurantium*, of which a single specimen has been met with at Lenham, is a well-known and characteristic Lower Pliocene form. Spines of *Diadema* are common; as are the tubes of *Ditrupa subulata*, an annelid usually found at depths varying from 60 to 120 fathoms.

CHAPTER V.

ST. ERTH BEDS.

The only remaining deposit of Older Pliocene date that has yet been discovered in Britain is a small outlier, occupying a few acres, close to the village of St. Erth in Cornwall. St. Erth lies in the valley, formerly in all probability a strait, that divides the high land of the western part of Cornwall from the rest of the county. This valley connects Mounts Bay with St. Ives Bay, and only reaches 80 feet above the present level of the sea on the low watershed which divides the northward from the southward flowing streams.

Between the village of St. Erth and the Vicarage, which lies about a quarter of a mile to the east, there are some gently sloping fields, in which pits have been opened for sand, and to obtain clay for puddling for some engineering works at Penzance. Nothing would have been known about the fossiliferous deposit if it had not been for the economic value of the clay, which led to the deepening of the largest of the pits, so that the underlying unweathered shelly clay was reached. Everywhere the angular rubbly deposit known in the west of England as "Head" overlaps the clay, so that without artificial sections we should not have suspected the presence of anything between the Head and the palæozoic rocks. This widespread and deep deposit of Head makes it impossible to trace the exact limits of the clay, but the outcrop of slate and elvan at several points in the neighbourhood shows that the basin must be of limited extent, probably less than a quarter of a square mile, certainly under one square mile.

The pit in question lies close to the Vicarage on the north-west side, and occupies a field sloping towards the north-west. The beds exposed in it, as far as can be seen, dip in the same direction, but at a higher angle, so that the clay thins out altogether towards the Vicarage, and it is not improbable that the Vicarage buildings may rest almost directly on the solid rock.

The sections constantly vary as the faces of the pit are cut back, and they may now be much altered, as the clay has been extensively dug since my visit in 1886. At that time heavy rains had somewhat obscured the lower part of the section, but the north-east face showed :—

	Feet.
Angular Head - - - - - -	3
Head and clay mixed - - - - -	2
Mottled clay - - - - - -	6
Blue shelly clay (base not seen) - - -	1½

Towards the south-east, where the ground rises, the deposits change very fast, for only 40 feet from where the last section was measured they were found to be as follows :—

	Feet.
Head - - - - - - -	3
Clean mottled clay - - - - -	7
Loam with small quartz pebbles - - -	$\frac{2}{3}$
Sand - - - - - - -	1

Still higher, in the old sand pit in the adjoining field, the Head rests directly on sand, as it does also along the south-east and the greater part of the south-west face. Along the north-western face of the pit the clay seems to be most developed and continuous for we find at the north-west corner :—

	Feet.
Head - - - - - - -	7
Brown clay - - - - - -	4
Blue clay - - - - - -	3
Gravel (not seen at the time of my visit).	

Further west the solid rock rises again, and elvan is met with in a quarry close to Mellanear Lane, though a small overgrown pit nearer to the village seems to have been opened in gravel, perhaps the same gravel that underlies the fossiliferous clays. On the eastern side the deposit appears to abut against a cliff or steep bank, killas being visible at Carnabargas and again at Trenhayle. On the north the extent of the Pliocene Beds may be somewhat greater than I ventured to lay down on the map which I prepared of the locality, on the scale of 25 inches to a mile, for some fields on the south-west side of Trelissick are flat, and apparently have a deep soil. However no sections were visible, and it is safer not to extend the outlier north of Mellanear Lane.

The small outlier of marine beds at St. Erth probably owes its preservation to the position of the strata in a hollow or channel between a boss of slate and a hard projecting elvan dyke. This part of the spur of Palæozoic rocks happens also to be so isolated from the high land by small valleys, that no streams have been able to collect and to erode it ; the Pliocene deposit can therefore suffer little from denudation, even under the heavy rainfall of Cornwall.

As it seemed probable that other outliers might be preserved in a similar way, the whole valley was searched from Marazion to Lelant, but without result. Everywhere except near St. Erth the contours were so distinctly those of fluviatile denudation acting on hard strata that it was hopeless to expect anything but Palæozoic rocks, more or less capped by Head. The only place where other similar outliers are likely to be found is on the watershed which lies about a mile to the west and south-west of the village of St. Erth. Here also is a ridge little affected by denudation, but unfortunately no sections were exposed ; any pits, however, that may be opened in this area should be carefully examined.

The exact age of the St. Erth clays still remains somewhat doubtful, and so many views have been expressed on this subject

during the seven years since the deposit became known, that one feels disinclined at present to express any positive opinion, though the mollusca of the deposit seem to me to point unmistakably to the Older Pliocene period.

The earliest account of the marine shells was published in 1882* by Mr. Whitley, who, however, called the clay Boulder Clay, and spoke of it as conclusive evidence of glacial action. To this paper Mr. G. B. Sowerby added a note on the ten species of mollusca collected by Mr. Whitley. Five he determined as common living British forms; two, a *Trochus* and a *Turritella*, he stated did not belong to any British species; one, *Nassa mutabilis*, is Mediterranean and not British; a *Fusus* (*Euthria*) "is certainly not a Boreal species"; and a *Trochita* he compared with one found in the Barton Clay. Yet Mr. Whitley remarked that "some of them show indications of glacial belongings."

The determination of the Pliocene age of the St. Erth clay was the last work of S. V. Wood, jun., who died before his paper on the subject was published.† He came to the conclusion that the deposit nearly corresponded in age with the Red Crag, but observed that "the character of the Mollusca, as a whole, is essentially southern, no peculiarly arctic shell having as yet occurred." A provisional list of about 50 species of Mollusca was added by Wood, but was not published, being withdraw for revision; he, however, alludes to the distribution of about 16 of the species.

In the discussion that followed the reading of this paper Dr. Gwyn Jeffreys, who had examined the mollusca, said that "there were 44 or 45 species, out of which 11 or 12 are recent and 33 or 34 extinct." Dr. Jeffreys added that "he was not clear whether the St. Erth deposit was of Older Pliocene or possibly of Upper Miocene age."

During the same discussion Robert Bell, who had greatly assisted S. V. Wood in the determination of the specimens, objected to the deposit being called Miocene, and regarded it as nearly of Crag age (he does not state whether Upper or Lower Crag).

At the same time that Wood was studying the Mollusca Mr. Millett was working out the Foraminifera.‡ He recognised the Tertiary age of the deposit, but added that the exact position could not be determined without further investigation. He gave a list of 120 species and varieties, and mentioned that there were others undescribed. According to Mr. Millett the Foraminifera "indicate such a fauna as might be found in the shallow seas of a sub-tropical climate."

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* The Evidence of Glacial Action in Cornwall and Devon. *Trans. Geol. Soc. Cornwall*, vol. x. pp. 132–141.

† On a new Deposit of Pliocene Age at St. Erth, near the Land's End, Cornwall. *Quart. Journ. Geol. Soc.*, vol. xli. pp. 65–73. (1885.)

‡ Notes on the Fossil Foraminifera of the St. Erth Clay Pits. *Trans. Geol. Soc. Cornwall*, vol. x. pp. 213–216, 222–226. (1885.)

The next paper was by Messrs. Kendall and Robert Bell,* who by Mr. Wood's desire had undertaken to carry on the work after his death. These authors added largely to the fauna of the deposit, giving a list of 72 species of mollusca, and observing that 20 more seemed to be unknown either in a recent or fossil state. They also mention the occurrence of numerous other invertebrates, including four species of Bryozoa (all Coralline Crag forms), a *Balanus*, several species of swimming crabs, *Echini*, Annelids, calcareous Sponges, an Alcyonarian, plates of Holothurias, and spicules of a Tunicate closely allied to *Leptoclinum tenue*. The authors analyse the list of Mollusca, and come to the conclusion that the deposit is of about the age of the earlier portion of the Red Crag; but to account for the absence at St. Erth of the Boreal species which give so marked a character to even the oldest part of the Red Crag, they are obliged to postulate a land-barrier across the Atlantic from Scotland to Greenland, thus cutting off in Pliocene times the Arctic seas from any communication with the seas of the west of England. The Red Crag area is considered to have been at the same period freely open towards the north.

This view of the comparatively recent age of the strata does not seem to be borne out by the evidence of the Mollusca. I think, moreover, that we should be cautious before raising barriers across the Atlantic to account for the undoubted great difference between the climatic conditions under which the St. Erth Beds and the Red Crag were respectively deposited.

The next note on the subject occurred in an article published during the same year (1886)†, wherein after a study of the deposits at Lenham, and St. Erth, as well as the older Crags of Suffolk and Belgium, I concluded that they were all of approximately the same age, but did not deal with the St. Erth fauna, except to suggest that it points to a considerable depth of water.

At the Manchester meeting of the British Association the late R. G. Bell‡ read a short additional note giving some further particulars and criticising my conclusions as to the depth of water shown by the clays. He observed that the majority of the Mollusca were such as inhabited the laminarian zone, and did not extend to a greater depth than about 15 fathoms.

Mr. Kendall has since continued his researches into the character of the fauna of the St. Erth clays, but at present his results are still unpublished, though I believe he has been able considerably to add to the lists.

Messrs. Wood, jun., Kendall, and Robert Bell have had so much experience in studying the Mollusca of the Crag that I differ from them with the greatest hesitation, especially as I have only had an opportunity of examining a portion of the fauna of the St. Erth clay. Their list of the Mollusca seems, however, to lead to

* On the Pliocene Beds of St. Erth. *Quart. Journ. Geol. Soc.*, vol. xlii. pp. 201–215. (1886.)

† On the Pliocene Deposits of North-Western Europe (C. Reid). *Nature*, vol. xxxiv. p. 341. (1886.)

‡ The Pliocene Beds of St. Erth, Cornwall. *Rep. Brit. Assoc.* for 1887, p. 718.

a quite different conclusion as to the age of the beds from that adopted by them. When, further, we take into account the physical conditions which must have prevailed while the clays were being deposited, as well as the list of species found in this small outlier, it appears to me that the depth of water there indicated must have been considerably greater than these observers have supposed.

The following are the species recorded by Messrs. Kendall and Bell. The list is given as it stands in their paper, but a number of the specific names given by S. V. Wood, (jun.)* refer to MS. species as yet neither figured nor described; these are consequently omitted from the tables at the end of this Memoir.

Mollusca of the Pliocene Beds of St. Erth.

Calyptræa chinensis, *Linn.*
Cerithium reticulatum, *Da C.*, var.
Chiton, sp.
Columbella sulcata, *Sow.*
Conovulus pyramidalis, *J. Sow.*
Cyclostrema nitens, *Phil.*
Cylichna truncatula, *Brug.*
Cypræa avellana, *Sow.*
Defrancia linearis, *Mont.*
Eulima intermedia, *Cantr.*
——— polita, *Linn.*
Fusus corneus, *Linn.* (=F. lignarius).
Homalogyra atomus, *Phil.*
Hydrobia terebellata, *Nyst.*
———————, var. conica.
Jeffreysia diaphana, *Alder.*
——— globularis, *Jeff.*
Littorina subaperta, *Wood.*
Murex, sp.
Nassa granulata, *Sow.*
——— mutabilis, *Linn.*
———————, var. St. Erthensis.
——— recticostata, *Bellardi.*
——— serrata, *Brocchi* (=N. reticosa, *Sow.*).
——— solida, *S. Wood.*
Natica millepunctata, *Lam.*
——— sordida, *Phil.*
Odostomia acuta, *Jeff.*
——— clathrata, *Jeff.*
——— eximia, *Jeff.*
——— insculpta, *Mont.*
——— interstincta, *Mont.*
——— pallida, *Mont.*
——— plicata, *Mont.*
——— rissoides, *Hanley.*
——— spiralis, *Mont.*
——— unidentata, *Mont.*
——— (Chemnitzia) costellata, *Grateloup.*
——— plicatula, *Brocchi.*
Pleurotoma brachystoma, *Phil.*
——— costata, *Da C.*
Pleurotoma costato-striata, *S. Wood, jun. MS.*
Ringicula acuta, *Phil.*
Rissoa Montagui, *Payr.*
——— partim-cancellata, *S. Wood, jun. MS.*
——— pentadonta, *S. Wood.*
——— reticulata, *Mont.*
Skenea planorbis, *Fabr.*
Trochus Adansoni, *Payr.*
——— adriaticus, *Phil.*
——— multistriatus, *S. Wood, jun. MS.*
——— noduliferens, *S. Wood.*
——— zizyphinus, *Linn.*
Turritella triplicata, *Brocchi.*
Utriculus hyalinus, *Turton.*

Artemis exoleta, *Linn.*
Cardita aculeata, *Poli.*
Cardium echinatum, *Linn.*
——— papillosum, *Poli.*
——— tuberculatum, *Linn.*
——— strigilliferum, *S. Wood.*
Kellia, sp. nov.
Lasea rubra, *Mont.*
Lepton nitidum, *Turt.*
Lucina borealis, *Linn.*
Mactra solida, *Linn.*
Montacuta bidentata, *Mont.*
——— ferruginosa, *Mont.*
Mya arenaria, *Linn.*
Nucula nucleus, *Linn.*
——— proxima? *Say.*
——— sulcata, *Bronn.*
Ostrea edulis, *Linn.*
Pecten maximus, *Linn.*
——— opercularis, *Linn.*
Pectunculus glycimeris, *Linn.*
Solen ensis, *Linn.*
Tapes aureus, *Gemelin.*
——— pullastra, *Wood.*
——— virgineus, *Linn.*

* To prevent confusion it may be observed that S. V. Wood of Messrs. Kendall and Bell's paper is S. V. Wood, junr., not the author of the Crag Mollusca.

As there appears to be a considerable number of undescribed species, besides the MS. names given in the above list, it is difficult to arrive at the relative proportion of living and extinct forms contained in the deposit. Messrs. Kendall and Bell mention about 20 more that do not seem to be known, either in a fossil or recent state, making a total of 92 species and marked varieties of mollusca discovered up to the time their paper was written. Of these about 38, or 41 per cent., appear to be extinct, a proportion exactly corresponding with that found in the Coralline Crag. Probably when the St. Erth fauna is better known the proportion of extinct species will be found to be greater, for species dying out will commonly be represented by fewer individuals than species with a wide range in time. As far as the per-centage test is of value, and I do not like to trust very much to it, it appears to show that the St. Erth clays are fully as old as the Coralline Crag.

Another test of the age of these newer Tertiary deposits is afforded by a consideration of the climatic conditions indicated by their fauna. The evidence from this source likewise indicates that the St. Erth Clay is Older Pliocene, not Newer Pliocene. In the last chapter we traced the gradual change of temperature which is revealed by the Older Pliocene beds as they are followed through Holland, Belgium, and Suffolk, to Kent, that is to say from north-east to south-west. We now find that the St. Erth clays yield a fauna such as might have lived in warm seas like those wherein the sands of Lenham were deposited. They are marked by a similar enormous preponderance of southern mollusca; at the same time the species found at the two localities are different.

I will now give the reasons which have led me to consider that, notwithstanding the character of the included fauna, the St. Erth clays were deposited in so great a depth as 40 or 50 fathoms. This is the more necessary as a glance at the list of species, or even an examination of a collection of the fossils, will seem at first strongly to confirm the justice of Mr. Bell's criticism, that most of the species belong to the Laminarian zone, that is to say, that they did not live in a greater depth than about 15 fathoms. The list by itself clearly points to that conclusion. We have, however, to deal with a much more complicated question, for firstly we must inquire under what physical conditions the beds could have been deposited; secondly, we must take into account the close proximity of shoaler water; and thirdly, we ought to separate the species which lived on the spot from those that belonged to the shoaler water, and were merely washed or dropped into this basin.

First with regard to the question of the physical conditions which prevailed, it has already been pointed out that the clay lies in a pass or valley dividing two tracts of high land. The fossiliferous strata occur at almost exactly 100 feet above the present sea-level, though unfossiliferous sands, probably belonging to

the same series, rise about 30 feet higher near St. Erth Vicarage The land rises rapidly to the south-east, so that we find an elevation of 255 feet only 600 yards away, and it should not be forgotten that the land was once still higher, for since Pliocene times this hill has yielded the mass of angular rubble which now covers the fossiliferous bed. If the depth at which the clay was deposited were only 15 fathoms this elevation must then have been dry land, in fact the shore line must have coincided with the 190 foot contour, only 400 yards away. What evidence is there of this close proximity of land? The littoral shells, such as *Patella* and *Littorina*, which everywhere occur in thousands on rocky shores between tide-marks, are entirely absent, as are *Scrobicularia, Cardium edule*, and *Hydrobia ulvæ*, which inhabit the sheltered creeks and estuaries. The only evidence of the neighbourhood of land is the finding of a specimen of the littoral air-breathing *Conovulus* (*Melampus*) *pyramidalis*; the empty shells of recent species of this genus will, however, float long distances when full of air.

Again the lithological character of the clay points to deposit in fairly still water; but as this area would be exposed to the force of the Atlantic swell, though somewhat sheltered by the high lands to the west, it is difficult to conceive of such clays being laid down in a less depth than 40 fathoms, especially when we take into account the enormous force of the waves at St. Ives and Penzance, which are now as much sheltered from the prevalent wind as St. Erth could have been.

Assuming that the clays were deposited in 40 fathoms, the total depression of this area must have amounted to about 340 feet, for the fossiliferous deposit now lies about 100 feet above the sea-level. Under such conditions the character of the district would be greatly altered. Cornwall would be transformed into a scattered archipelago, divided by numerous straits and channels with very uneven bottoms, exactly as we find among the Scilly Islands at the present day. On this assumption the high land close to St. Erth would become a submerged shoal, reaching the lower part of the laminarian zone, but not rising above the sea-level. Like all such rocky shoals it would be covered with a thick growth of the sea-weeds which form the favourite haunts of the various plant-eating Rissoas and Odostomias. Anyone who has collected floating sea-weeds will have noticed how largely they assist in the transportation of these shells. Thus a deep hollow close to a forest of oarweeds must often be filled with the shells of the laminarian zone to such an extent as almost entirely to mask the true character of the fauna proper to the depression. Besides this the submarine slope was here so steep that multitudes of shells must have been washed down by the to-and-fro motion of the water and dropped into any sheltered hollow below the range of wave action. It is in this manner that I think we can account for the character of the fauna of the St. Erth clay; the mollusca are mainly the species that lived on the shoal close by, and the

absence of truly littoral forms is due to the distance from the shore.

During the examination of this part of Cornwall I was struck by the rounded hummocky contours of the lower portions, contours that did not seem to be due to fluviatile action, for in hard rocks like the slates and granites of Cornwall subaërial denudation tends to develop bold scarps rather than flowing curves. This smoothed character appeared, however, to be exactly what one might expect if the land had been submerged to the extent of 300 or 400 feet, and everything below that level had been planed and smoothed by the Atlantic waves. Such a submergence ought to have left traces in ancient beaches; we accordingly find at St. Agnes Beacon, which rises to 627 feet, a series of clays and sands at exactly the level needed, *i.e.*, between 300 and 400 feet.

The sands and clays of St. Agnes Beacon have long been known,* and as far back as 1839 they were referred by De la Beche† to the Tertiary period, and pointed to as more ancient than the oldest of the superficial deposits. These strata nearly encircle the higher part of the Beacon, reaching, according to Dr. Boase, a height of 375 feet above high-water level. They have up till now proved entirely unfossiliferous, but their position is so unlike that of any of the raised beaches, and they correspond so well in level with the height at which we might expect to find littoral deposits of the age of the St. Erth clays, that it is safe provisionally to refer them to the same period.

The following section, observed by De la Beche on the north-east side of the hill, is deeper than any now visible:—

St. Agnes Beacon—north-east side.

	Feet.
Head of rubble, derived from the hill above, and named *Cobb*	3
Yellow sand	2
Brownish sand, with numerous planes (apparently those of deposit) dipping at an angle of 45°	11
Light-coloured mining clay	2
Blue clay	9
Yellow sand	4
White sand	4
Yellow sand	3
Pebbles, resting upon an uneven surface of slate	variable.

The strata vary greatly within short distances, and in the sections now exposed they are stained and mottled in such a way as to suggest the action of percolating rain-water. Any fossils that were originally contained in these sands and clays have probably been entirely dissolved out, for the beds seem to be nearly free from lime. No section is now visible of the thick bed of blue

* Hawkins, John. On a very singular Deposit of Alluvial Matter on St. Agnes Beacon . . . . . *Trans. Geol. Soc. Cornwall*, vol. iv. pp. 135–144. (1832.) Boase, Dr. H. S. Contributions towards a knowledge of the Geology of Cornwall, *ibid.* pp. 296–299. (1832.)

† Report on the Geology of Cornwall, Devon, and West Somerset. 8vo. pp. 258–260. (1839.)

clay mentioned by De la Beche, but should it be again exposed it would be advisable to wash the middle and lower portions for microscopic fossils.

Standing on this old beach of St. Agnes Beacon, one looks across a lower undulating country, out of which rise here and there bold hills or masses of high land with more rugged outlines. With this smoothed undulating plain lying at one's feet it is difficult to avoid the conclusion that it was formerly the bed of the sea, and that the distant hills rose, like St. Agnes Beacon, above the sea-level, converting Cornwall into an archipelago somewhat resembling the Scilly Islands at the present day. What may have been the date of this ancient submergence is difficult to prove in the absence of fossils; but we are unacquainted with any period to which it can belong unless it correspond with that during which the fossiliferous clays of St. Erth were being laid down. We may therefore provisionally refer the deposition of the strata at St. Agnes Beacon and some of the general sculpture of the surface in this part of Cornwall to the Older Pliocene period.

Crossing the Channel into Normandy, one finds in the low-lying peninsula of Cotentin small outliers of Upper Tertiary strata of different ages, resting on various rocks, from Devonian to Cretaceous. These have been thoroughly examined by M. G. Dollfus.* They are important as helping to show the relation of the Pliocene strata of England to those of the Continent, and also to the Faluns of the Loire; but Pliocene beds occupy almost as small an area in the north of France as they do in the south of England, and we need much more evidence before the minor divisions of deposits varying so greatly in character can be satisfactorily correlated.

The upper Tertiaries of Cotentin are thus divided by M. Dollfus:—

Pliocène	Marnes à *Nassa* de Saint-Martin d'Aubigny.
	Conglomérat à Térébratules de Saint-Georges-de-Bohon.
Miocène	Falun à Bryozoaires de Saint-Eny.

The Faluns are about 25 feet thick, and consist of soft calcareous strata, formed almost entirely of much-worn fossils—Bryozoa, Corals, Mollusca, and Echinids. The actual shell in both Gasteropods and Lamellibranchs has always disappeared. In lithological character this deposit resembles the Coralline Crag, and it contains also a similar fauna, though several of the species mentioned by M. Dollfus have not been found in England. On palæontological grounds M. Dollfus correlates the Faluns of Cotentin with the Miocene Faluns of the Loire; the areas are, however, widely separated, and the list of fossils is not yet very large.

The next deposit—the conglomerate with *Terebratula grandis*—appears to rest on an eroded surface of the underlying

* Esquisse des Terrains Tertiaires de la Normandie. Mém. Soc. Géol. Normandie sur l'Exposition Géol. du Havre, en 1877, p. 478.

"Miocene" beds, and according to M. Bonissent it certainly underlies the "marnes à Nassa." In lithological character it is usually an agglutinated ferruginous gravel with rolled fossils, hard in some places, sandy in others. A clayey sand, with pebbles and rolled bones at its base, has been discovered by M. Vasseur near Gourbesville.* This sand has yielded a large number of fossils to the researches of MM. Vasseur and Dollfus, and is evidently of the same age as the conglomerate. Of 143 species determined by M. Dollfus† about 91 are known in the Coralline Crag, and only 53 in the Red Crag; at least 85 of the species are still living in Europe, the per-centage of living Mollusca being identical with that found in the Coralline Crag.

The Pliocene fauna of Normandy is so important for comparison with that of the English Pliocene beds that a column is devoted to it in the tables at the end of this volume. The mollusca point to conditions very similar to those indicated by the shells from St. Erth, a large number of them being species found on a rocky bottom; most of them indicate the lower part of the laminarian zone, but the truly littoral *Patella* is also represented. The sands seem therefore to point to shoaler water than the clays of St. Erth, for Gourbesville is not dominated by any high land, and we appear in this case to have the fauna that lived at the same depth as that in which the sands were deposited.

The next division of the Pliocene series found in Cotentin is the *Nassa* marls of Saint-Martin-d'Aubigny. These marls M. Bonissent has seen resting on the bed with *Terebratula grandis*. M. Dollfus describes the beds as consisting of greenish clay, having a thickness of 5 or 6 metres, and situated at 2 metres above the mean level of the sea. The most marked characteristic of the fauna of Bosq d'Aubigny, yielding 50 per cent. of living species, is its southern facies; according to M. Dollfus, it is the upper Red Crag of England, with 75 per cent. of Subapennine species.‡ If this deposit be truly of the age of the Red Crag of England, and of the Scaldisian of Belgium, it is difficult to understand the markedly southern character of its fauna, while that of even the oldest portion of the Red Crag is somewhat northern. It is also surprising to find a stratum containing only 50 per cent. of recent species *overlying* one containing as much as 60 per cent. Of course if the Straits of Dover did not yet exist, or were obliterated by a rise of land which cut off the English Channel from the North Sea, a considerable discrepancy in the temperature of the water might be thus accounted for. The general facies of the fauna, and the small per-centage of recent species would, however, incline one to refer the *Nassa* marls to the older Pliocene period rather than to the newer Pliocene. The difference between the fossils of Gourbesville and those of the *Nassa* beds is more suggestive of slightly varying conditions than of any great lapse

* *Bull. Soc. Géol. France*, ser. 3, vol. vii. p. 743. (1879.)

† Esquisse des Terrains Tertiaires, p. 520.

‡ *See also* G. Dollfus, Essai sur l'Extension des Terrains Tertiaires dans le Bassin Anglo-Parisien, *op. cit.* p. 584–605.

of time. These strata are therefore classed provisionally with those of Lenham and St. Erth, and with the Coralline Crag; the correlation of the English and foreign Pliocene deposits will, however, be again alluded to in the chapters on the Red Crag and on foreign equivalents (pp. 98, 99, 222, 223).

In the foregoing description of the different Older Pliocene deposits, especial attention has been drawn to the height above the sea-level at which each is now found, and to the depth of water indicated by the included fossils. The data show that instead of the faunal zones varying according to the varying height of the beds above the sea level, or depth below the sea, the Older Pliocene beds of St. Erth and Lenham, the Coralline Crag, and the Diestian of Antwerp and of Utrecht all point to very similar bathimetric conditions, and were all probably laid down in depths ranging between 30 and 50 fathoms. If the movements which have elevated the Lenham deposits 620 feet above the sea had been uniform in amount over the whole of the area dealt with in this Memoir we might expect to find evidence in some of the Older Pliocene strata of seas of considerable depth, and of a corresponding deep-water fauna. Taking Lenham as our starting point, with an indicated rise of 860 feet—obtained by adding the present elevation of the strata above the sea to the depth at which they were laid down—we ought to find indications of a submergence to the extent of 840 feet (140 fathoms) in the Coralline Crag, and of 2,000 feet (330 fathoms) at Utrecht.

A Pliocene fauna of over 300 fathoms would be most interesting to examine, but of such a fauna no trace has yet been detected anywhere in North-Western Europe. All the Older Pliocene deposits, though now occurring at such different levels, are shown by their included fossils to have been laid down in about the same depth of water. Though differing much in mineral composition at the various localities, they nevertheless agree as closely in regard to their fossils as the very different nature of the sea-bottoms would allow us to expect. The whole 1,143 feet of Pliocene and Pleistocene beds at Utrecht consists of essentially shallow-water deposits, pointing to a continuous depression. In Holland subsidence apparently tends to affect the same area again and again.

On the other hand, the question arises whether the elevation of the Wealden axis was still in progress during the Pliocene period. That the greater part of this enormous disturbance had been completed before that period seems proved by the absence of any Pliocene beds in the Hampshire or London basins, in the synclinal folds parallel with the Weald. There is, however, evidence of less violent movements of upheaval in the different levels at which Older Pliocene beds now occur, and it is probable that those geologists are right who maintain that the direction of the movements in areas of subsidence or elevation remains the same during long periods. Holland may thus have undergone continued, though probably intermittent, depression since the early part of the Pliocene period; so as to allow of the accumulation of a great

thickness of shallow water Newer Tertiary beds. The axis of the Weald, including the Downs near Lenham, has been correspondingly elevated. Suffolk was little affected, and the deposits were therefore, in that district, thin and largely of organic origin.

Were we to assume that the present positions of the Pliocene deposits of the north-west of Europe represent the relative depths at which the beds were originally laid down, a curious difficulty would present itself in any attempt to compare the Pliocene and recent sea-bottoms. Any deep depressions in the seas around England are now filled with cold water and contain an Arctic fauna. In similar depths during the Pliocene period one would expect to find a similar fauna, unless there existed, as in the Mediterranean, a barrier to cut off the Polar currents, or unless there was at that time no cold area at the Pole. Neither of these explanations seems allowable.

A few years since the Coralline Crag was generally considered to be our only representative of the Older Pliocene period, and as it did not rise much above the sea-level, it was often assumed that great part of the rest of England was dry land. Now we know that Pliocene beds cap the highest parts of the North Downs, and indicate a subsidence sufficient to submerge the whole of the east and south of England, except a few hills. We find that, instead of the Older Pliocene period being one of elevation, there must have been widespread submergence, though the indications of irregular movement prevent us feeling confident, in the absence of fossiliferous deposits, as to the extent of the submerged area.

Among the hard rocks of Cornwall denudation does not appear much to have changed the general configuration of the country since the Older Pliocene period. Moreover the Pliocene deposits in that district were probably never continuous or thick, but merely formed patches in sheltered places and around the shores, the rest of the sea-bottom being rocky. In the south-east and east of England, however, the case was different, for the rocks of that region are soft and much more easily denuded. The position of the Lenham beds, at the very edge of an escarpment, over 600 feet above the sea, indicates that the great valleys of the Thames and Weald have to a large extent been excavated since Pliocene times.

CHAPTER VI.

RED CRAG.

Between the Coralline Crag and the next overlying deposit there is a considerable break and erosion of the older strata, so that the Red Crag rests indifferently and irregularly on either Pliocene or Eocene beds, and in one place, towards its western limit, it even touches the Chalk. There is also at the base of the higher division a marked change in the lithological character of the Crag, for instead of soft organic limestones, we find coarse quartzose sand with a more littoral fauna. The climatic conditions had also changed, and in place of a warm sea, the mollusca point to cold currents, bringing Arctic species, unknown in the older deposits. These boreal forms become more and more abundant as we examine higher beds, till at last they give the dominant character to the fauna (*see* Plate IV.). To what extent the Crag of Walton may fill the gap between the Coralline and the Red Crags is still an open question, for lithologically it is thoroughly Red Crag, but among the fossils there is a large proportion of southern species, and the Arctic forms so conspicuous in higher zones are almost entirely absent.

The literature relating to the Red Crag is somewhat extensive, but a great portion of it has already been referred to in the Chapters on the Nodule Bed, and on the Coralline Crag, while the titles of the rest of the papers will be found in the Bibliographical Appendix to this volume. It therefore only remains to allude to such of the authors as have published important observations, or whose works are of historical interest.*

The earliest scientific account of the Red Crag seems to be that given by S. Dale, in 1704, in his description of the cliff at Harwich.† This paper is especially valuable as preserving a record of an outlier now entirely destroyed by the sea. To the reprint of his paper a section of the cliff and four well-drawn plates of Crag fossils were added. Dale combated the opinion of the artificial or recent origin of this deposit, pointing out that similar beds occur also at Walton and Bawdsey, and that the common reversed whelk of the sands is not found living in the

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* This account of the literature relating to the Red Crag is mainly taken from Mr. Whitaker's Geology of the Country around Ipswich, &c. (*Memoirs of the Geological Survey*), 1885.

† *Phil. Trans.*, vol. xxiv. (No. 291) pp. 1568, 1569. Reprinted in The History and Antiquities of Harwich and Dovercourt. 4to., pp. 18, 19, and Appendix. Edit. 2. 1732.

adjacent seas. He also showed that the Crag overlies the London Clay—though subsequent observers overlooked his description and transposed the beds.

In 1745 the Rev. R. Pickering* drew attention to the discovery of the value of Crag shells as manure, through the accidental upsetting of a load on cultivated land.

In 1811 J. Parkinson† pointed out that certain of the Red Crag species seemed to belong to extinct forms; and between 1812 and 1819 Sowerby‡ published figures of many of the shells.

The several memoirs and maps, published between 1815 and 1819, by William Smith, which form the foundation of stratigraphical geology, add nothing to our knowledge of the Crag, and through them all, owing to an unfortunate confusion of the Boulder Clay with the London Clay, the Crag is placed beneath the latter deposit. Smith used the term "Crag," but only in the local sense of shelly masses in the sands, not as the name of a stratigraphical division.

In 1822, the Rev. W. D. Conybeare and W. Phillips§ concluded that the Crag is "probably the newest bed of the Upper Marine formation," or in other words, newer than the Bagshot Beds and the Oligocene strata of the Isle of Wight.

The next important addition to our knowledge of these strata was made in 1833 by Lyell,‖ who had devoted a good deal of time to the examination of the beds in the field during the year 1829. Lyell gave a number of sections of the Red Crag, and for the first time referred to the per-centage of living and extinct species.¶ He classed the beds as older Pliocene and paralleled the Crag with the Subapennine deposits.

In 1835 Mr. E. Charlesworth** separated the Red Crag from the Coralline Crag; and gave the name "Red Crag" to the Upper division, correlating it with the Crag of Norfolk. Two years later he considered†† that the Mammaliferous Crag of Norfolk is not an extension of the Red Crag, but a newer deposit. In several of his papers between these dates he spoke of the mixture of shells of different ages in the Red Crag.

The Rev. W. B. Clarke in 1838‡‡ criticised Lyell's view of the impossibility of separating the Drift from the Crag, an opinion given up in later editions of Lyell's works.

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* A Letter concerning the Manuring of Land with Fossil Shells [Woodbridge]. *Phil. Trans.*, vol. xliii. no. 474, p. 191.

† Organic Remains of a former World, vol. iii. 4to. London.

‡ Mineral Conchology. 6 vols. 8vo. London.

§ Outlines of the Geology of England and Wales, pp. 10–13.

‖ Principles of Geology, vol. iii. pp. 19–21, 61, 171–177, 181, 182, 203–206. Appendix, pp. 47–49, 51.

¶ The determination of the shells was made by Deshayes, who compared the shells from Suffolk with those of Touraine and Piedmont.

** *Phil. Mag.*, ser. 3, vol. vii. pp. 81–94.

†† *Rep. Brit. Assoc.* for 1836, *Sections*, pp. 84–86, and in *Mag. Nat. Hist.*, n. ser., vol. ii., pp. 40–43. (1838.)

‡‡ Letter on the Non-identity of Suffolk Diluvium and Crag. *Mag. Nat. Hist.*, ser. 2, vol. ii. p. 285.

In 1839 Lyell* followed Mr. Charlesworth as to the superposition of the Red on the Coralline Crag, the former resting on a denuded surface of the latter; and described the junction of the two at Sutton, where the Coralline Crag has been perforated by *Pholas*, and in parts forms a low buried cliff against which the Red Crag rests. He described the so-called Fluvio-marine Crag of Southwold, but seems to include therein the overlying pebbly sands at Easton Bavent cliff, and treated of the Norwich Crag at greater length. He accepted the opinion of Desnoyers that the Red and Coralline Crags may be of the same age as the Faluns of Touraine, as, though the fauna of the former is of a northern character, whilst that of the latter is southern, yet the two faunas depart almost equally from the nearest existing marine fauna. He regarded the Norwich Crag as older Pliocene, the Red and Coralline Crags as Miocene.

In the same year S. V. Wood commenced his papers on the fossil shells of the Crag; these he afterwards expanded into the valuable Monograph published by the Palæontographical Society between the years 1848 and 1882. In the Introduction to the first part of his Monograph Wood classes the Coralline Crag as Miocene, the Red Crag as Pliocene, and the Mammaliferous Crag as Pleistocene.

In 1849 Prof. Prestwich† established the fact that the fossiliferous clay and sand of Chillesford overlie the Red Crag, and sometimes overlap on to the Coralline Crag. These Chillesford Beds were, he thought, the result of tranquil accumulation, whilst the Red Crag showed every sign of a disturbed condition of the waters. He gave a list of pits in Coralline Crag, in Red Crag, and in Chillesford Clay, between the Alde and the Butley River.

In 1852 Lyell‡ noted the occurrence, near the top of the shelly Crag at Wherstead, of a bed of unrolled flints, with some flint-pebbles, the upper parts of the stones being encrusted with barnacle-shells, whilst the lower surfaces are free, and inferred that the action of the currents which brought the Crag here was suspended for a time, so that the smallest pebbles were not overturned, as otherwise the barnacles would be found on the lower side or on both sides.

The first paper on the Crag by S. V. Wood, jun., appeared in 1864.§ The Red Crag is divided by this author into two parts, one with none of the characters of a deposit formed under water, the other with those characters. Of the former there are four stages (beach stages), whilst the latter is more or less horizontal. The lowest three stages of the beach Crag are not quite constant in their direction (that is, the direction of the so-called false-bedding), and cannot be well identified in different sections; but the uppermost stage, from its thickness and from its having been

* On the Relative Ages of the Tertiary Deposits commonly called "Crag," in the Counties of Norfolk and Suffolk. *Mag. Nat. Hist.*, ser. 2, vol. iii. p. 213.

† *Quart. Journ. Geol. Soc.*, vol. v. p. 345–353.

‡ *Rep. Brit. Assoc.* for 1851, *Sections*, pp. 65, 66.

§ *Ann. Nat. Hist.*, ser. 3, vol. xiii. pp. 185–203, pl. xvii.

less denuded by a succeeding stage than the others have been, can be accurately identified. The direction of the oblique laminæ of this fourth stage is from N.N.E. to S.S.W. at angles varying from 25° to 35°, south of Hollesley.

The constancy of direction and the parallelism of the planes preclude, according to Wood, any idea of false bedding under water, and in one place only in Suffolk (Butley) is there any indication of a water-deposit. At Walton Naze, however, below other Crag, a greyish-brown bed, without stratification, yields shells in the condition in which they died, bivalves with the valves united (which happens in no other Red Crag bed) and not containing those derived Coralline Crag shells that make up so much of the mass elsewhere.

The fifth or water-deposited stage does not always occur over the lower stages. It is under this stage alone that the workings of phosphatic nodules occur, and where beach stages rest on the London Clay the nodule-bed does not occur. This bed thins off as the fifth stage Crag leaves the clay and rises over the beach stages. Though this stage is water-deposited yet the shells are not like those of the above-noted bed at Walton, but are as worn as those of the beach stages, from which they seem to have been mainly derived.

The beach stages, in Wood's opinion, seem to have resulted from a sea forced back by the growth of beach which it had heaped up, until, by a slight subsidence, the sea planed down the old beach and again began the process of beaching up.

At Chillesford the fifth stage passes up into the sands and clays described by Prestwich (1849). Our author concluded that the Fluvio-marine (Norwich) Crag is as old as the Red Crag, and probably older than the fifth stage.

Six pages of the paper are devoted to the Drift, and an appendix gives the places of sections of Red Crag, noting the stages shown.

In 1865 the same author* referred to the subjects of his paper of the previous year, inclining to the belief that the horizontal Crag is the re-deposit of the material of the beach Crag, and doubting that the former is part of the Red Crag. He corrects the statement in his last paper that phosphatic nodules occur only under the horizontal Crag, being satisfied that some thin traces referred to this stage from the presence of nodules, really belong to the beach series.

In 1866 the Rev. O. Fisher† came to the conclusion that the Chillesford Clay underlies the Fluvio-marine or Norwich Crag (an error abandoned afterwards), having found brown clay at the bottom of the Thorpe pit, near Aldborough. Beneath the Chillesford Clay (in the Aldborough and Orford District) he noted sand, with shells of *Mya* in their burrows, then other sand, and then the Red Crag.

* Remarks in Explanation of the Map of the Upper Tertiaries of Norfolk, Suffolk, etc. (with Map and Sections as separate sheets). Privately printed.

† *Quart. Journ. Geol. Soc.*, vol. xxii. pp. 19–28.

R. A. C. Godwin-Austen* in the same year criticised the percentage test of age as liable to fluctuation; parallelled the Scaldisian beds of Antwerp with the Red Crag, both consisting largely of derived shells; limited the Crag sea in Suffolk at Bentley, Ipswich, and Woodbridge, but included as of Crag age beds which are now known to be later, such as those of Grays and Kelsey. He likewise gave a map of the Crag-sea area. He thought that there is a great break between the Crag and the Boulder Drift.

In the same year S. V. Wood,† controverting Mr. Fisher's conclusion, noted above, agreed with that of his son, as to the passage upwards of Red and Norwich Crag into Chillesford Beds, and gave the name *Scrobicularia* Crag to the top, or horizontal, stage of the Red Crag. He referred chiefly to palæontological evidence, which shows one of the most rapid faunal changes, measured by the thickness of the beds in which it occurs. The oldest part of the Red Crag is, he thought, palæontologically nearer to the present time than to the Coralline Crag; and the newer deposit shows evidence of change by stages, the oldest having some affinities with the Coralline Crag, but more with the Mediterranean sea, whilst the newer stages have few shells, and those of northern type. The oldest stage is that of Walton Naze, the fauna of which shows a connection with more temperate seas, and an absence of northern forms. The next division is that from which were got the chief part of the shells described in the Monograph on the Crag Mollusca, and which occurs between the Stour and the Deben, and on the left bank of the estuary of the latter: it has mostly a highly oblique bedding, referred to beach action; shows an intermingling of the Walton fauna with the northern one of the succeeding horizons; and includes some shells probably derived from the Coralline Crag. The next division occurs around Butley, Chillesford, and Sudbourne, and though in structure like the last, has a dissimilar fauna, but with many forms that occur at Sutton. Above this is the uppermost division of the Red Crag, marked by the incoming of *Scrobicularia piperata*, the fauna of which is small in number of species. Separated from this by a few feet of sand is the Chillesford sand (Mya-bed of Mr. Fisher). S. V. Wood, jun., added some diagram-sections in illustration, with a list of the actual sections on which they are based.

In 1868 R. A. C. Godwin-Austen‡ gave a summary of our knowledge of the Crag, reviewing the conditions under which it was deposited, remarking that the Red Crag is a complex assemblage, in spite of its small vertical size, and that at Walton Naze alone do we find this old sea-bed in its original state, undisturbed, elsewhere the Red Crag being re-arranged and relatively of shallow water accumulation.

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* *Quart. Journ. Geol. Soc.*, vol. xxii. pp. 229–232, 237–239, 245, 246.

† *Ibid.*, pp. 538–552.

‡ *Geol. Mag.*, vol. v. pp. 469–478; *Geol. Nat. Hist. Repertory*, vol. ii. p. 229; and *Rep. Brit. Assoc.* for 1868, *Sections*, p. 70. (1869.)

In 1869 the Rev. O. Fisher* regarded the Norwich Crag and the Red Crag as of the same age, as they seem to pass into one another; gave up his opinion that the clay under the Crag at Thorpe (near Aldborough) is Chillesford Clay; and remarked that the change from Red Crag to Norwich Crag seems to occur where the two provinces are partially separated by a ridge of Coralline Crag.

In 1870 Prof. E. Ray Lankester,† from the occurrence of different shells in the higher and lower parts of the Red Crag, inferred that this deposit represents a considerable time. In its earlier period the Red Crag had a fauna not very different from that of the Coralline Crag, and with some survivors from the still earlier Diestian; in its later period none of these forms remained, but boreal forms were added. Contemporaneously with the newer Red Crag the Norwich Crag began to be formed, continuing, Prof. Lankester thought, to be deposited in Norfolk to a later time than we have evidence of in Suffolk.

In the following year Prof. Prestwich contributed a set of three papers on the Crag. Of these the second‡ is devoted to the Red Crag, which is described as lying in an excavated area in the Coralline Crag, wrapping round the isolated reefs of the latter and filling the hollows between [it should be noted that the reefs are comparatively small and the hollows of wide extent]. He divided it into two only, instead of the five stages of Wood, the lower part marked by oblique lamination, and the upper by horizontal bedding. The phosphate-bed occurs at the base of the lower division, the direction of the lamination of which varies to almost all points of the compass, and this false-bedding is most general in the upper part of this division. Sometimes beds have been eroded before the deposition of those over-laying them. He had seen ripple-marks in only one place, Bawdsey Cliff, where each of the clayey laminæ of one bed had a ripple-marked surface. Another feature sometimes seen there seems, he thought, to show that the shoals of the Red Crag sea were sometimes left dry, their surfaces fissured by drying, and the cracks filled with the matter of the bed next thrown down: while elsewhere a layer has been pressed down into those below, causing a wavy structure, and the upper part has then been planed down. The introduction of the oxide of iron, which colours the beds, seems to have been subsequent to their formation, and in one case it has segregated in flattened concentric shells, the longer diameter of which may be many feet in length.

Prof. Prestwich further points out that the lower division generally abounds in shells, mostly broken, double shells not being common; and that save the old shore at Sutton, no place can be easily found where the shells are on the spot where they lived. Notwithstanding the great number of shells, the abundant

* *Geol. Mag.*, vol. vi. p. 142.
† *Quart. Journ. Geol. Soc.*, vol. xxvi. pp. 493–502.
‡ *Ibid.*, vol. xxvii. pp. 325–356. (1871.)

species are few. In places, especially away from the centre of the district, the beds are almost shell-less, or the shells occur in patches. This may be due either to the original absence of shells, or to their removal by percolation of rain-water, for where the beds are consolidated by iron-oxide casts are sometimes met with.

The author alludes to the difficulty of marking the line between the two divisions (the upper of which he once called "the unproductive sands," from the absence of fossils, which, however, have since been found in places), and notices sections showing a line of erosion between them. The upper division is the Chillesford Sands, succeeded by the Chillesford Clay, which is also classed with the Red Crag.

Details of many sections are given in the same paper, with lists of the fossils from some. The fossils are of two kinds, those proper to the formation and those derived from other formations. Of these latter, which are important, some may have been doubly derived, from the Coralline Crag, which got them from older beds. With regard to the Mollusca there is a difference of opinion as to which are derived species; but the author is inclined to think that the greater number of the species found in the Suffolk Crag but not in the Norfolk Crag have been derived from the Coralline Crag.

The lamination that Wood referred to beach-action was regarded by Prof. Prestwich as having been produced by the shifting of shoals and sand-banks at the bottom of the sea, which was shallow and studded with reefs of Coralline Crag; whilst in winter the distant Chalk and Tertiary shores were fringed with ice, which floated off large flints and deposited them in the Red Crag. The constant shifting of materials would result in the heavier parts, as bones, pebbles, and phosphatic nodules, being left behind and thus tending to accumulate in the basement-beds. The consequence of the reconstruction is that the shells are much broken up. The currents seem to have flowed from a direction varying between east and south-east, and the Red Crag sea seems to have been open to the north, but probably closed on the south. There is no distinction in the fossils from top to bottom of the lower division, after the deposit of which there was a slight subsidence. From the lower part of the upper sands having been formed from the lower Red Crag there is a similarity in mineral composition; but as the sea-bed became more depressed the sands became finer, until they passed up into the micaceous sands and clays of the Chillesford Beds.

In the third part of this set of papers* Prof. Prestwich referred chiefly to the Norwich Crag area, and concluded that this was divided from the more open sea of the Red Crag by a barrier of Coralline Crag, streams flowing into the northern area, and carrying in land and freshwater shells. A list of the Mollusca of the Red and Norwich Crags, to a great extent on the authority of Dr. J. G. Jeffreys, is given.

* *Quart. Journ. Geol. Soc.*, vol. xxvii. pp. 452–496.

In the same year (1871) Messrs. A. and R. Bell* suggested the terms Lower, Middle, and Upper Crags, instead of Coralline, Red, and Norwich. They held that there is no evidence for separating from the fauna of the Red Crag any species except such as are of Eocene or older date, regarding the signs of a supposed derivative origin as not really such. They proposed to class as Middle Crag the lower deposits, from Walton Naze westward to Bentley and eastward to Butley and Hollesley, as Upper Crag the uppermost beds of the Red Crag, the Scrobicularia Crag, and the Norwich Crag. There is no order of succession physically, but only palæontologically. The fauna of the Red Crag has two aspects, a deep-water one and a shallow-water one, and this explains the difficulty in comparing different pits.

In 1871 Dr. J. E. Taylor† concluded that the Norwich fluvio-marine Crag is an extension of the Red Crag, that, after depression, the Upper Norwich (marine) or Chillesford Crag was deposited, and that there is an unbroken sequence from Coralline Crag to the latest Drift deposit.

Mr. A. Bell‡ in the same year controverted Dr. Taylor's view that Chillesford sand occurs at the Butley Crag Pits and gave a long list of the fossils found there. It should be noted that he classed Chillesford Beds as Pre-Glacial, as distinguished from Crag.

In 1872 Mr. A. Bell§ reviewed Prof. Prestwich's papers. He thought that the presence of Diestian fossils in the Crag may be explained otherwise than has been supposed, and defended his views of the year before.

In the same year Messrs. A. and R. Bell‖ gave a fuller version of their paper of 1871, with a review of some of Prof. Prestwich's work, and a long list of fossils.

S. V. Wood, jun., and Mr. F. W. Harmer,¶ treated of the beds with which we are now concerned, giving a map and sections. They regarded the oblique lamination of the Red Crag as different from false bedding, and as the result of beach-action (as in Wood's paper of 1864), the deposit being the remains of a set of banks that were more or less dry at low tides and from time to time partly swept away and again accumulated. If the mass of the Crag had been deposited under water the large stones, often so abundant at its base, might be expected to be found scattered throughout. The conclusions of S. V. Wood's paper of 1864 are adopted here, the stone-bed is regarded not as a land-surface, but as the result of cliff-waste, and the mammalian remains of the Red Crag are looked upon as wholly derivative, occurring only in the nodule-bed at the base, which is regarded by those authors as clearly a bed of erratics.

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* *Geol. Mag.*, vol. viii., pp. 256–263.
† *Ibid.*, pp. 314–316.
‡ *Ibid.*, pp. 450–455.
§ *Ibid.*, vol. ix. pp. 209–215.
‖ *Proc. Geol. Assoc.*, vol. ii. no. 5, pp. 185–218.
¶ Supplement to the Crag Mollusca, Part 1, pp. v–xiii. (1872.)

Mr. G. Scott* in 1872 included in the Red Crag beds of rough red sand without shells, at the top, and described the bone-bed.

Lyell in 1873† noticed the gradual lowering of temperature shown by the shells of the Crags, those of the Coralline Crag representing a climate like that of the Mediterranean; those of the Red Crag one like that of our own seas, and those of the Norwich Crag being almost Arctic. He thought that the large unrolled white-coated flints of the nodule-bed were probably carried by ice.

Next year,‡ in describing the Red Crag, the same author compared it to shifting sandbanks, like those of the Dogger Bank.

In the same year S. V. Wood,§ reviewing the palæontology of the Crag, remarked that species formerly abundant had of late eluded search, though within a few yards of, and at the same horizon as, the place of former occurrence; while some once thought rare had become more plentiful. He criticised the work of Jeffreys on Crag Mollusca, and thought that if any period can be called "the cradle of the British Mollusca," it is the Red Crag rather than the Coralline. The list of extraneous fossils (of his paper of 1859) was thought by him to need additions. The only part of the Red Crag free from derivatives is that at Walton Naze. The Red and Fluvio-marine Crags and the Chillesford Beds he regarded as parts of one formation, during the accumulation of which only slight changes in the position of sea and land occurred. The lists of the Marine Mollusca given in Wood's Monograph show almost the same per-centage of extinct forms in the case of the older Red Crag as in that of the Coralline.

In this year Mr. Whitaker drew attention to a great extension of the Crag area, in the south-western part of Suffolk, around Sudbury. He also recorded the discovery of Red Crag at Thaxted, in Essex.‖

In 1877 Dr. J. E. Taylor, in an account of an excursion to the Crag District,¶ suggested that the Baltic represents the condition of the later period of the Red Crag better than anything else, its water being partly brackish, with freshwater shells side by side with marine ones, as in the Fluvio-marine Crag.

S. V. Wood, jun., and Mr. F. W. Harmer** in the same year, referring to the unfossiliferous sand that often occurs above the shelly Crag, showed that it seems in some places to pass down into the Crag by thin seams of comminuted shells; that at others the bedding is independent of the shelly Crag beneath; and that sometimes it has the same oblique lamination as the Crag,

* 19 *Ann. Rep. Brighton Nat. Hist. Soc.*, pp. 64–68.

† The Geological Evidences of the Antiquity of Man. Ed. 4. 8vo. *London.* pp. 248–254.

‡ The Student's Elements of Geology. Ed. 2. 8vo. *London.* p. 176. (1874.)

§ Supplement to the Crag Mollusca. Part ii., pp. 190–221. (1874).

‖ *Quart. Journ. Geol. Soc.*, vol. xxx. pp. 403–405.

¶ *Proc. Geol. Assoc.*, vol. v. no. 3, pp. 108–113.

** *Quart. Journ. Geol. Soc.*, vol. xxxiii. pp. 74–78.

apparently disconnected masses of which are imbedded in it here and there. Notwithstanding certain difficulties, these authors now accept Mr. Whitaker's view that this sand is Crag deprived of its shells by the infiltration of water, casts of the shells being left where there is ironstone; for in one case a layer of pebbles extends continuously from the shelly Crag into the sand. They do not agree with Prof. Prestwich in referring this sand to the upper or Chillesford division of the Red Crag, because the casts of shells in the ironstone are not of species characteristic of the newer (or Butley) part of the Red Crag or of the Chillesford Beds.

In the same year, when describing the patches of Red Crag at Walton Naze, Beaumont, and Harwich,* Mr. Whitaker suggested that the shell-less sand above was but the result of the alteration of the shelly Crag below, and in a note devoted to this subject† showed that what had been supposed to be a line of erosion was only one of irregular alteration, the lines of false-bedding of the shelly Crag being sometimes continued into the sand above; that this irregular dissolving away of the shells explains the apparently isolated masses of Crag in the sand, and that this unfossiliferous sand extended beyond where the shelly Crag had been observed.

In 1877 Mr. E. Charlesworth, in reprinting a notice, by Prof. Lankester, of the Crag fossils in the Ipswich Museum (from the *Suffolk Chronicle* of August 4), recurred to the subject of the prospective exhaustion of the nodule-bed, and in the following year‡ he gave a note on English Crag History, referring especially to his earlier work, and remarking that the Red Crag is the record of a past state, like that where our Crag cliffs are now being washed by the sea, in the bed of which new formations are in progress, partly made up from remains of the present fauna, and partly from the fossils carried away from the land.

In the same year (1878) Mr. Whitaker described the sections of the westerly extension of the Crag (at Sudbury)§ noted in his paper of 1874, and suggested that possibly some sands that had been classed as Drift might turn out to be Crag, a question also alluded to in a later Memoir.‖

In 1879 S. V. Wood in his Second Supplement to the Crag Mollusca,¶ treated of the introduction into Crag lists of new species on unsatisfactory evidence, either from doubtful identification, or as being simply derivatives, and gave an addition to the Synoptical List of Mollusca in the First Supplement.

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* The Geology of the Eastern End of Essex . . . (*Memoirs of the Geological Survey*), pp. 10–16. (1877.)

† *Quart. Journ. Geol. Soc.*, vol. xxxiii. pp. 122, 123.

‡ Fossil Exploration of Suffolk Crag (Orford Castle) and Hampshire Eocene Cliffs, pp. 8. 8vo. *London.* Privately printed, 1878.

§ The Geology of the N.W. Part of Essex . . . (*Memoirs of the Geological Survey*), pp. 30, 31.

‖ The Geology of the Neighbourhood of Stowmarket, (*Memoirs of the Geological Survey*), p. 5. (1881.)

¶ *Palæontographical Soc.*, pp. i., ii., 54, 55.

In 1880 S. V. Wood, jun.,* remarked that the formations from the Red Crag upwards—except the recent deposits—should be studied as one group, for they were all accumulated, he thought, during one continuous movement of depression and re-elevation. The whole of the strata included in this group he classed as Newer Pliocene. The mode of formation of the different deposits was fully treated of by this author, who traced step by step the physical changes which he considered to have caused the variations in the character of the strata and in their included fauna.

In 1882 appeared the last contribution from the pen of S. V. Wood,† which gave a list of the Mollusca from the Red Crag at Felixstow, distinguishing the species that have been derived, firstly, from beds older than the Red Crag, secondly, from earlier Red Crag beds; also a supplementary list for Walton Naze, by R. G. Bell. He referred to the contrast between the Crag of Walton and that of Felixstow and stated that the fragmentary condition of many shells at Felixstow, which are abundant in a perfect state at Walton, must be owing to derivation. Between the deposit of these two divisions of the Red Crag certain species, he thought, had ceased to exist in the Crag sea, and others had been brought in, whilst in the Butley Crag this change is further marked. He traced the sequence of events during the Pliocene period in England, and re-stated the conclusion that all but the top part of the Red Crag was formed between high and low-water mark as banks which were continuously undergoing destruction and re-accumulation.

S. V. Wood, jun., added to this communication some remarks in correction of the map and section in the First Supplement (1872); and whilst classing much of the sand over the Red Crag as Lower Glacial, allowed that some is merely Crag from which the calcareous matter has been dissolved.

In 1884 R. G. Bell‡ remarked that few traces of land and fresh-water shells have been found in the Red Crag, which is the more notable as the deposit must have been formed at no great distance from shore. All the specimens are of living British species of wide range, and are first found in this bed. This author noted the finding of three additional species in the lower part of the Crag at Walton Naze, and remarked that their present geographical range, compared with that of the land-shells from the Butley Crag, leads to the same conclusion as that deduced from the marine species, the shells of Walton being mainly southern, whilst at Butley there are more of northern kinds.

In 1885 Messrs. Whitaker and Dalton§ described in detail the greater part of the Red Crag area; and during the years

* *Quart. Journ. Geol. Soc.*, vol. xxxvi. pp. 457–459.

† In the posthumous Third Supplement to the Crag Mollusca, edited by his son, S. V. Wood, Jun., pp. 13–24.

‡ *Geol. Mag.*, dec. iii. vol. i., pp. 262–264.

§ The Geology of the country around Ipswich, Hadleigh, and Felixstow. (*Memoirs of the Geological Survey*), pp. 29–71.

1886* and 1887† the rest of the Geological Survey Memoirs referring to that region appeared.

From the foregoing historical account of the literature relating to the Red Crag it will be understood that there is no definite division between Red Crag and Norwich Crag, and that if we here keep them separate it is more as a matter of convenience in describing different areas than as indicating any leaning to the opinion that they represent distinct periods. What appears to happen is, that successive stages of the upper Crag overlap each other as they are followed northward. At the southern extremity of the area, at Walton, we find the oldest Red Crag, a deposit yielding a fauna closely allied to the Coralline Crag. A few miles northward this is lost, and the Red Crag of Sutton and Butley, with many arctic mollusca, rests directly on the Coralline Crag. Above the typical Red Crag near Butley comes a higher and lighter coloured division, the "Scrobicularia Crag" of S. V. Wood, which seems to correspond very closely with the Norwich Crag. Proceeding northward we pass an area where the strata may be called either Red Crag or Norwich Crag; but in the Waveney Valley the upper division has overlapped the lower ones and rests directly on Eocene or Chalk, the strata belonging undoubtedly to the Norwich Crag type. A corresponding overlap to the northward of still newer beds causes the Weybourn Crag, which in the Bure Valley overlies the Norwich Crag, to rest directly on the Chalk near Cromer.

For the purpose of this Memoir it will scarcely be necessary to describe all the sections in the Red Crag, especially as the details will be found in the Geological Survey Memoirs relating to the different areas. Instead of going over the same ground again we will select the sections of interest, and those illustrating the changes the deposits undergo as they are traced northward. We shall by this means avoid overloading the Chapter with detail, for Crag pits are found in hundreds, and are constantly becoming overgrown, or are ploughed over, while others are opened.

A glance at the Map which forms the frontispiece to this volume will show better than any description the area over which the Red Crag extends. But it should not be forgotten that the present extent of the strata does not necessarily correspond with their original importance, and that, to the southward at any rate, Red Crag must once have covered a wider area, for outliers cap several of the hills. An outlier at Sudbury shows that it must also have extended further to the west.

Commencing with the southernmost of these outliers—that on the low hill at Walton Naze—we find a thin stratum of Crag, occasionally shelly, lying between the London Clay and some newer clays apparently belonging to the Chillesford Series. If it were not for the interesting fauna found in this sand, little notice

* The Geology of the country around Aldborough, Framlingham, Orford, and Woodbridge. (*Memoirs of the Geological Survey*), pp. 12–19.

† The Geology of Southwold, and the Suffolk Coast from Dunwich to Covehithe. *Ibid.*, pp. 6–15.

would be taken of the Red Crag at Walton, for it is thin, of small extent, and a large portion of it is decalcified. S. V. Wood, jun.,* and Prof. Prestwich† both give diagrammatic sections of Walton Cliff, in which the marked tendency of the different Pliocene strata to overlap on to the London Clay is distinctly shown. Mr. Whitaker, who has recently studied the deposits, notes the following section made up from observations taken at many points.‡

Cliff-section at the Naze, 1871.

Clayey soil.
Fine gravel up to 7 feet or more.
Chillesford Beds ? Light-coloured (grey and brownish), more or less bedded sandy clay, loam, and clayey sand; here and there with flints, flint pebbles, and quartz-pebbles, and sometimes a little sand; often with a layer of pale purplish clayey sand, sometimes a thin peaty layer (in places with well-preserved wood), and sometimes pebbles and flints at the bottom. Up to 7 feet.

Red Crag:
- Brown and buff sand, false-bedded; sometimes with many small quartz-pebbles, and some small phosphatic nodules: 5 or 6 feet, but not constant, and sometimes passing into the bed below.
- Brown and grey sand with shells and ferruginous nodules, false-bedded; sometimes with thin layers of hardened clay and, in the upper part, many small black phosphatic nodules and small quartz-pebbles.
- Thin bed of phosphatic nodules and phosphatized bones at the bottom in places.

London Clay, brown at top, but soon getting grey.

When re-examined in 1886, the northern part of the section showed little-altered shelly Crag, consisting in places of light-coloured, sometimes almost white, shell-sand with scattered whole shells. Except *Pholas* imbedded in cement-stone, no shells with the valves united were met with, and the great majority of the mollusca were broken and water-worn. At a distance the Crag appears to be fairly evenly bedded, with alternating bands of reddish and buff sand. But this bedding proves to be deceptive, when examined more closely, for the ferruginous lines merely run parallel with the clays above and below the Crag, the greater part of the Crag being strongly false-bedded, though perhaps not at such high angles as in most other sections. Oxidation here produces a result the exact converse of that ordinarily met with. At Walton false-bedded sands seem to be evenly-bedded, but more generally oxidation of the beds tends to give a deceptive appearance of current-bedding.

It has already been observed that the principal interest of the Walton Crag lies in the close resemblance of its fauna to that of the Coralline Crag. At Walton, according to S. V. Wood, the fauna is also nearly free from the mixture of derived specimens from other deposits, such as occur so abundantly at nearly every

* *Quart. Journ. Geol. Soc.*, vol. xxii., p. 548 (1866); and Supplement to the Crag Mollusca. Introduction. *Pal. Soc.* (1872). [Section xxi.]
† *Ibid.*, vol. xxvii. p. 333. (1871.)
‡ Geology of the eastern end of Essex. (*Memoirs Geol. Survey*), p. 13. (1877.)

other Red Crag section.* Mr. Wood thus analyses the list of mollusca† :—

Mollusca from the Walton Crag.

British and not Mediterranean	13
British and Mediterranean	61
Mediterranean and not British	14
Neither British nor Mediterranean	10
Not known living	50
Total	148

Reducing these figures to per-centages, for convenience of comparison with the Coralline Crag, the numbers are :—

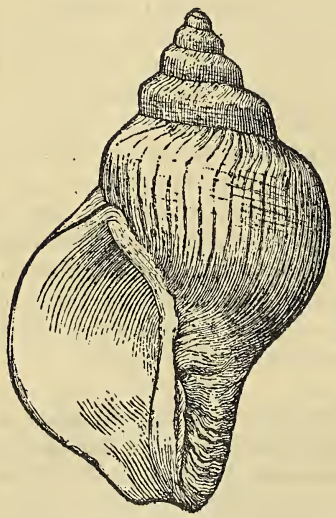
	Coralline Crag.	Walton Red Crag.
British and not Mediterranean	5·1	8·8
British and Mediterranean	39·4	41·2
Mediterranean and not British	13·0	9·5
Neither British nor Mediterranean	6·1	6·8
Not known living	36·3	33·8

This table shows at a glance the slow change that the fauna is undergoing. Extinct species are fewer, southern species are more rare, and those belonging exclusively to British or northern seas are more plentiful. The real extent of the difference is, however, not brought out by this test. If we take into account the number of individuals, the increase of northern forms is very marked in the Crag of Walton, and we find also that characteristic Upper Pliocene forms, such as the reversed whelk, *Trophon antiquus* (Fig. 11), occur plentifully, though quite unknown, either in England or in Belgium, in the older deposit. Most of the common mollusca of the Walton Crag are

Fig. 11.

Trophon antiquus, Linn., *reversed variety.*

Half natural size.



* Prof. Prestwich observes, however, that fragments of Coralline Crag limestone do occur at Walton.

† Supplement to the Crag Mollusca, p. 219.

also common species in the next higher division, but certain of the most abundant shells of the higher Red Crag seem to be entirely absent from Walton. Among these are the three species of *Tellina*, *T. obliqua*, *T. lata*, and *T. prætenuis*, which often constitute a considerable part of the bulk of the Crag, and also the *Nucula Cobboldiæ* and several species of *Leda* found nearly everywhere in the upper Red Crag.* Very little is yet known of the land fauna of the older portion of the Red Crag, but it is interesting to find that of four species of *Helix* (*H. rysa*, *H. lens*, *H. incarnata*, and *H. lactea*), found at the base of the deposit at Walton, one is extinct, and the other three have an exclusively southern range. A complete list of the fossils from Walton will be found in the Appendix.

On the high ground at Beaumont (about 5 miles west of Walton) occurs shelly Red Crag, from which John Brown, of Stanway, obtained over 90 species of mollusca. The area of the outlier is about a quarter of a square mile, but there is now no section. The sand evidently belongs to the newer part of the Red Crag, for it contains several of the northern species missing at Walton. Red Crag also underlies later deposits on the hills between Little Oakley and Harwich. The outlier at Harwich, described by Dale in 1704,† has now almost disappeared, though as late as 1872 Mr. Whitaker was still able to find a few fragments of shell at one spot on the top of the cliff.

The other outliers in Essex, except those of Thaxted and Stoke mentioned below, are of little interest. They show disconnected outcrops beneath the newer deposits which cap low hills near the south bank of the Stour, between Harwich and Nayland. At Wrabness the Nodule Bed has been worked, and ferruginous sands with casts of shells were noticed by Mr. Whitaker as occurring at Mistley, Langham, and Boxstead. None of the sections now show shelly Crag, though such is mentioned by the Rev. W. B. Clarke‡ as found at Blackbrook Hill.

North of the River Orwell the Red Crag covers a wide expanse of country, though commonly outcropping from beneath newer deposits along the valleys. The southern limit of the more continuous area follows an approximately east and west line, passing near Manningtree and Nayland, and bending northward and eastward to the south of Hadleigh, and then to Ipswich. Still further west an outlier at Sudbury shows that Crag undoubtedly extended much further in that direction, and overlapped most of the Eocene beds, till it rested directly on Thanet Sands, and in places touched the Chalk. Even 16 miles beyond Sudbury traces of Crag occur at Thaxted, in Essex, but there, and at Stoke, they are so mixed with glacial deposits that it is

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* *See also* Introduction to the Crag Mollusca.—*Palæontographical Society*, p. vii.

† *Phil. Trans.*, vol. xxiv. (No. 291), pp. 1568, 1569.

‡ *Trans. Geol. Soc.*, ser. 2, vol. v. p. 362. (1840.)

uncertain whether the beds are in place. It should be remembered that the movement of the ice has been from east to west, and in the east of England there is often a considerable transport of loose deposits to the west. The following is taken from Mr. Whitaker's account of these interesting outliers, which were first discovered during the Geological Survey of the district.*

The most westerly traces of the Crag noticed were on the south of Thaxted, in a deep water-course half a mile south-south-east of the church. There Messrs. Whitaker and Penning found some small phosphatic nodules and a piece of phosphatized bone in a thin layer of gravel at the bottom of sand, lying on London Clay; besides some larger phosphatic nodules on the surface further south, at the junction of the sand and clay.† Mr. Whitaker also found a piece of phosphatized bone in the flint-bed at the base of the sand resting on the Chalk, near Stoke. A mass of shells was said to have been found at one spot just above this flint-bed, and some that were preserved were the common shell at Sudbury, *Purpura lapillus*.

At the north-east edge of Sudbury, by the side of a footpath running north-east from near the top of Suffolk Road, two small chalk-pits (Webb's) gave the best sections of the Crag visible in 1873–5. The further of these showed the following beds :—

Boulder Clay, at one spot, cutting down to the greensand of the Thanet Beds.

Red Crag.
- Ferruginous sand, slightly false-bedded; in parts a light-coloured grit, with broken shells, unbroken specimens of *Purpura lapillus*, layers of ironstone, and at the bottom a firm bed of this material. A line of pebbles, &c. lies about 2 feet from the bottom. Up to 6 feet thick.
- Layer of flint-pebbles, phosphatic nodules, and flints, 3 to 12 inches.

Clayey greensand, with green-coated flints (base of Thanet Beds), 1½ to 2 feet.

Chalk.

Other sections in the immediate neighbourhood are similar, the greatest thickness of Crag seen being about 10 feet.

The following revised list of the fossils from the Crag at Sudbury suffices to prove that the strata belong to the Red Crag, but does not show whether they should be referred to the upper or lower division :—

Littorina littorea.
Nassa reticosa, var. elongata.
Natica, sp.
Purpura lapillus, var. crispata.
Trophon antiquus, var. contraria.
Anomia ephippium.
Cardium Parkinsoni.
Mactra, sp.
Modiola modiolus.
Mya arenaria.
Mytilus edulis.
Panopæa?
Pecten opercularis.
Tellina, sp.
Balanus.

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* *See also* Geology of the N.W. part of Essex . . . . (*Mem. Geological Survey*) (1878), pp. 30 and 31, and *Quart. Journ. Geol. Soc.*, vol. xxx. p. 401. (1874.)

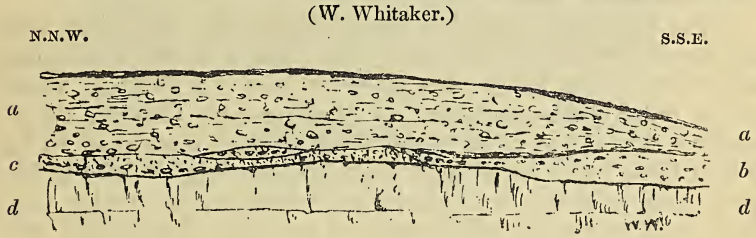
† The elevation is about 230 feet, a much greater height than the Red Crag reaches elsewhere.

About 5 miles north-west of Hadleigh, another outlier, in the Chalk Pit, marked on the Map, just south-westward of Monks' Eleigh Church, gave the section Fig. 12. Just to the left the Boulder Clay rests directly on the Chalk.

FIG. 12.

Section in Chalk Pit, Monks' Eleigh (about 25 yards long).

(W. Whitaker.)



a. Boulder Clay; 4 to 8 feet.
b. Coarse Gravel, at S.S.E., elsewhere only a trace, and finer; up to 4 feet.
c. Red Crag. Light-coloured sand, with iron-sandstone, ironstone (? cast of shell) and at the bottom flints, flint pebbles and phosphatic nodules, a piece of bone and several sharks' teeth; up to 2 feet.
d. Chalk with a few flints; 12 feet.

This is the furthest point to which the Red Crag has been traced in a north-north-westerly direction.

Bordering on the valleys of the Brett and Stour there are numerous outcrops of similar ferruginous beds, with casts of fossils, or only badly preserved specimens. These, however, are fully described in the Geological Survey "Memoir on the Country around Ipswich," and need not be re-described here. They are principally interesting as helping to connect the distant outliers, just alluded to, with the main mass, and in themselves are of little interest. The pits in which fossils are well preserved all lie east of this area.

The most westerly of the well-known sections in shelly Crag lie in the valley through which the Eastern Union Railway passes. Mr. Whitaker thus describes the "Bentley Pit."*

"The large Crag pit at Danes Barn, just east of Bentley Station, shows more than 30 feet of false-bedded sand, in great part a grit, mostly ferruginous but partly light coloured, partly compact and evenly bedded, with layers of iron-sandstone and of ironstone (also occurring in concretions) which sometimes contain impressions and casts of shells in the upper part of the section. There are gravelly layers, with phosphatic nodules, as well as flint pebbles, one of which layers (near the bottom) contains a good many angular flints. The bottom 4 to 7 feet is shelly Crag, the shells ending off at top regardless of bedding, the bottom gravelly layer (which shows a slight northerly dip), being above the shells on the south

* Geology of Ipswich, p. 46. (1885.)

and in them on the north. A few feet greater depth would reach the London Clay. I class the whole of the sand of this well-known section with the Crag, there being no real division in it, the absence of shells being due clearly to nothing but dissolution after deposit. The top part is inaccessible."

According to Mr. Wood the Crag of Bentley, though decidedly newer, is more closely allied to that of Walton than is any other part of the Red Crag; the northern shells so conspicuous elsewhere are scarce here.*

In the adjoining valley of Tattingstone, Mr. Whitaker notes that some sections showed clearly the relation of the ferruginous beds to the shelly Crag. He observes that "a Crag-pit nearly half a mile north-north-west of Tattingstone Church, on the southern side of and close to the farm, showed more than 20 feet of Red Crag (with some small faults), consisting of false-bedded sand, passing down irregularly into false-bedded shelly Crag. There were marly phosphatic nodules in certain layers, and lenticular masses of ironstone and ferruginous loam, chiefly without shells. The shelly Crag was very rich in *Pectunculus*, and with a tendency to layers of *Fusus contrarius*. Some of the lower part was made up of broken-up shells."

"A small pit on the eastern side of the little valley, eastward of the farm named Bentley Lodge, gave the most conclusive proof of the dissolution of the shells of the Crag by infiltration of carbonated water having been the cause of the irregular junction of the shell-less brown sand with the ordinary shelly Crag, the section being as follows:—Very coarse dark brown sand, almost all a grit indeed; with a gravelly layer, 1 to 2 feet thick, above the middle, containing phosphatic nodules and ferruginous casts of shells, the stones small and scattered. Just under the gravelly layer a little iron-sandstone, with casts of shells, below which the sand is false-bedded and passes down into the shelly Crag, the line between being clearly one of dissolution of the shells and not of erosion, as it cuts across the beds, to a lower level towards the stream. Near the bottom is a second bed, 1 to 1½ feet thick, of small scattered pebbles and phosphatic nodules, with iron-sandstone, and, moreover, with shells or casts of shells, according to the position of the bed with regard to the line of dissolution, the bed being at one part in the shell-less, and at another in the shelly sand."†

In the pit at Park Farm, Tattingstone, we meet with clear evidence of the erosion which the Coralline Crag underwent previous to the deposition of the Red Crag. The section is now obscure, but Prof. Prestwich has published‡ a sketch of it as formerly seen; this, with his consent and by permission of the Council of the Geological Society, is here reproduced:—

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* Supplement to the Monograph of the Crag Mollusca, Introduction, p. vii. *Palæontographical Society*. (1872); and note to Synoptical List at end of Supplement, p. 203. (1874.)

† Geology of Ipswich, p. 47.

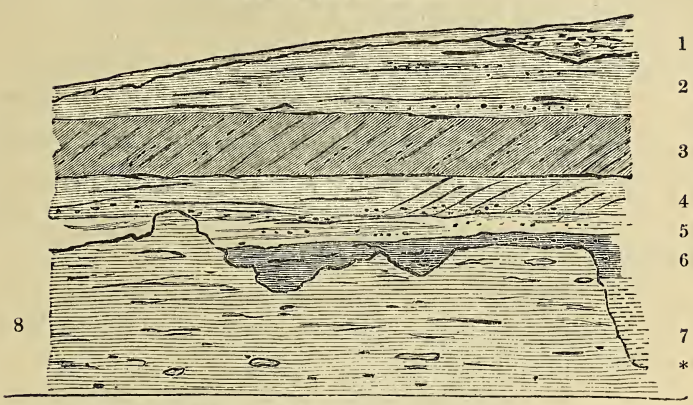
‡ *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 342. (1871.)

Fig. 13.

Section in a Pit at Park Farm, Tattingstone.

(Prestwich.)

Scale 12 feet to an inch.



1. Coarse gravel. Drift.

Red Crag 12 feet.
- 2. Ochreous sand with seams of ironstone, &c.
- 3. Crag with a few coprolites.
- 4. Light-coloured Crag.
- 5. White sand.
- 6. Brown loam.
- 7. Not described.

8. Coraline Crag; 8 feet.

* Face of old cliff; depth not shown.

Flat pieces of the thin Coralline Crag limestones are common in the Red Crag at Tattingstone.

Red Crag outcrops almost continuously along the right bank of the Orwell, from its junction with the Stour to Ipswich, but the sections merely show ferruginous strata or shelly Crag of the usual type,* and only one of them, about two miles south of Ipswich, need be referred to.

From the position assigned by Lyell to the following section of a pit, "about 500 yards south of the vicarage-houseof Wherstead,"† it would seem to be one not now open :—

> Sandy and gravelly beds, without fossils, 8 feet.
> Shelly red Crag: near the top a layer of unrounded flints, with some flint-pebbles. The upper parts of these stones encrusted with barnacles. One flint 22×16×7 inches. 10 to 12 feet.

The occurrence of these large unworn flints high up in the Red Crag is noteworthy, for though Chalk now outcrops within a mile of the spot, it was protected by Eocene strata during the deposition of the Crag. The flints were probably transported from a much more distant source and perhaps point to the agency of floating ice, for the large one mentioned by Lyell must have weighed about a hundredweight.

The left bank of the Orwell shows numerous sections of shelly Crag, which a mile or two south-east of Ipswich crops out in the

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* *See* Geology of Ipswich, &c. (*Memoirs of the Geological Survey*), pp. 48–50.

† Sir C. Lyell, *Rep. Brit. Assoc.* for 1851, *Sections*, p. 85.

river cliffs. At the Crag-pit (marked on the map), south of Moston Farm, and about a mile and a half from Trimley, Mr. Whitaker noted the following section in 1874, but in 1889 the lower strata were much obscured by talus, and the curious light-coloured bed at the base could not be examined:—

A little gravel, up to 5 feet.

Red Crag.
- Brown sand, with pebbles of flint and of quartz, and phosphatic nodules, especially in a layer at the bottom. This bed occurs at one part only (? a long lenticular mass): 0 to 3 or 4 feet.
- False-bedded shelly Crag, of a rather light colour, with pebbles and phosphatic nodules here and there, sometimes a thin layer at the bottom: 8 or 10 feet.
- A small wedge of pale purplish sand at one part: 6 or 8 inches.
- Brown rather clayey sand, with many short lenticular masses or nodules of whitish clay, flint-pebbles, and phosphatic nodules: 1 to 3 feet.
- Light-coloured (buff and grey), ironshot, fine, sharp, false-bedded sand, in places with small nodules of ironstone and very small pebbles of flint and of quartz.

"The tolerably well-marked and even junction of the lowest bed with that above showed a slight south-westerly dip as far as could be seen. Near the entrance there was a little shelly Crag, which seemed to dip under the lowest sand, but perhaps it is not in place, and I was told that London Clay had been found beneath the sand; it certainly occurs along the edge of the wood just below (south) at a level but slightly lower than that of the pit-bottom, if at all at one part."*

Possibly the lowest bed in the above section may be an undenuded portion of the sand from which the "box stones" and their peculiar fauna were derived, for in this area the masses in the Nodule Bed occur most abundantly and of the largest size. The composition of the Red Crag around Trimley is identical with that of the box stones, though the colours are different and the Crag is not phosphatized. The newer deposit has in all probability mainly originated from the destruction of this older Pliocene sand; it is quite possible that a number of the Red Crag mollusca may also have been washed out of the older bed. The possibility of derivation from strata of this age does not appear to have been taken into account, though Wood constantly warned geologists that a large portion of the Red Crag fossils was derived from the Coralline Crag. No doubt in the box stones the mollusca are nearly always found in the state of casts, but it does not follow that there were no perfect shells in the loose sands in which these concretions were formed. The lowest beds in any new Crag pits which may be opened around Trimley should always be carefully examined.

The other sections around Trimley call for no remark. Phosphate was formerly extensively dug, but none of the pits are now

* Geology of Ipswich, p. 52.

open and most of them have been ploughed over. The sections were of the usual character, and are fully described by Mr. Whitaker.*

Felixstow Cliffs show very fossiliferous Red Crag, extending for about two miles, and having a thickness in one part of about 30 feet. This well-known section is now much obscured by talus and by buildings, but in Bull's Cliff Mr. Whitaker noted five or six recognisable beds in the Red Crag, as below. Other portions show shelly Crag without any divisions.

	Feet.
1. A bed consisting chiefly of shells of *Mya*, but with some of *Cyprina*	6 or more.
2. An apparently lenticular mass of fine light-yellow sand, with clayey layers at top and bottom	
3. False-bedded Crag, the false-bedding almost wholly westward	6 or 7
4. False-bedded Crag, with loamy layers, the false-bedding westward	5 or 6
5. An even bed, of *Mya*, &c., rather white, with phosphatic nodules	about 2
6. False-bedded Crag, the false-bedding eastward, less shelly than the rest and with ferruginous layers.	
London Clay.	

In these cliffs the common shells are *Trophon antiquus*, var. *contraria*, *Purpura lapillus*, *Pectunculus*, *Tellina obliqua*, *T. crassa*, and *Mactra ovalis*, but most of the sections are now railed in—principally, I believe, to prevent collectors from pulling the cliff to pieces.

Seams of laminated clay occur in the Crag at several spots, and Prof. Prestwich† apparently refers the brickearth of the following section (bed 2), regarded by Wood as belonging to his Lower Glacial, to the Chillesford Clay.

Fig. 14.

Section in a New Road-Cutting just N. of the Convalescent Home, Felixstow.

(S. V. Wood, junr., 1882.)

1. Soil.
2. Reddish-brown brickearth, like that of the brickyard at Derby Road, Ipswich, passing down into—
3. Yellow sand with orange-coloured bands and patches, and some very fine shingle.
4. Dark brown bedded loamy sand.
5. Obliquely bedded Red Crag, without shells (decalcified).
6. Obliquely bedded shelly Red Crag.

There is no line between 5 and 6 really, the line here merely represents the ending off of the shells.

The coprolite pits at Felixstow are now (1889) all closed.

* Geology of Ipswich, pp. 52–54.

† *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 338. (1871.)

Following the right oank of the Deben northward from Felixstow, we find a nearly continuous outcrop of Red Crag, and as the Nodule Bed has been extensively worked, numerous sections have been seen, though many of them are now obscure. The descriptions need not be repeated, as there was nothing exceptional in the character of the deposit, and it was not thick.

Some of the best and deepest sections of the Red Crag are to be found in the tributary valley which extends westward, past Brightwell, nearly to Ipswich. In this valley phosphate has been more extensively worked than anywhere else, and through a greater thickness of overlying deposits. The most important sections visible in 1889 were, a small one a quarter of a mile north-west of Bucklesham Church, a good section close to Foxhall Lodge, and the large pit on the east side of Foxhall Hall. This last is now being extensively worked, with a long face 30 or 40 feet deep, and is perhaps the best pit for collecting from the Red Crag. Mr. Whitaker observed the following section in 1876 :—

Drift.—False-bedded gravel and sand, resting irregularly on the sand below; up to 15 feet (or more).

Red Crag.
- Ferruginous sand, with ironstone (impressions of shells), and scattered phosphatic nodules; of irregular thickness, being merely decalcified Crag.
- Shelly Crag, with a loamy ferruginous bed about the junction with the shell-less sand. The bottom 6 feet or so with phosphatic nodules and flints (some large), either in layers or scattered freely throughout. At the most easterly part (not then worked) there was at the bottom a loamy, firm, ferruginous bed, up to 3 feet thick, probably not far above the nodule-bed.
- Nodule Bed, at a depth of 33–36 feet; about a foot thick; with water, showing the presence of London Clay.

Abundance of the common Crag fossils can be obtained, but as usual it needs long search to find more than twenty species of mollusca. A large number of cetacean ear-bones and teeth occur.

Further east a new phosphate pit has lately been opened about a quarter of a mile south of Newbourn Church, and will probably prove a good place for collecting. Another section in this neighbourhood is thus described by Mr. Whitaker :—

"The large Crag pit, marked on the Map, at Newbourn, nearly a quarter of a mile north-east of the church, was about 40 feet deep, wholly in Red Crag, the eastern end being overgrown. The decalcified sand is in part rather light-coloured at top, partly fine, and is of course irregularly divided from the shelly Crag beneath. This latter contains a great variety of shells, many well preserved (and I believe this pit would prove a good collecting-place); it is mostly firm, so as to stand vertical in section, dark, false-bedded, and often with many phosphatic nodules and flints; at one part a nearly horizontal yellowish line occurs cutting across the false-bedding, and showing how little dependence is to

be placed on colour. At the western part of the pit the process of dissolution of shells was shown, the shelly Crag in places passing into a sort of marl, and there being many more or less vertical marly veins, the marl being the result of the dissolving away of shells from the sand. At the bottom of the pit there are springs, and the London Clay occurs at the lowest part."*

Continuing northward along the right bank of the River Deben we come to the extensive coprolite pits of Waldringfield—a well-known locality for Red Crag fossils.

"The large coprolite-working north-east of Waldringfield Church, which was nearly given up in 1876, except close to the road, gave the following section :—

Glacial Drift.—Gravel and sand, at the highest part; up to 8 feet thick, with soil.

Red Crag.
- Loamy ferruginous bedded layer, partly mottled.
- Sand, some fine.
- Shelly Crag.
- Nodule Bed; said to be up to 4 feet thick in places.

London Clay touched (not seen by me)."

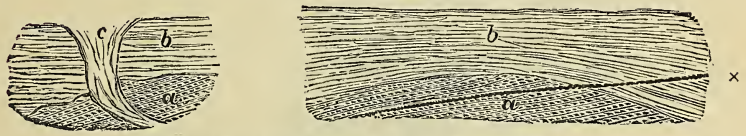
"Mr. Stollery, the foreman, who had a large collection of shells from the Crag, told me that the working had been carried to a depth of about 40 feet; that, in places, some six inches of Coralline Crag had been got beneath the nodule-bed; and that he had found *Pholas* shells bored into the London Clay to a depth of some inches."†

About a mile southward from Martlesham Church, is the site of an old coprolite-work, showing gravel over sand and shelly Crag; and it is probably here that Messrs. Wood and Harmer noted the section reproduced in Figs. 15 and 16.

Figs. 15, 16.

Sections in a Pit, South of Martlesham.‡

(S. V. Wood, jun.)



c. Pipe of sand crossing both altered and unaltered Crag.
b. Bedded sands, = *a*, altered.
a. Shelly Crag.
× Layer of flint-pebbles, running through both shelly Crag and sand.

The sections up the Fyn valley need not be described, and we can also pass over the intervening country and take at once the classical localities of Sutton and Shottisham. On the east side of the Deben, the Red Crag outcrops continuously from Woodbridge to the Butley River, rising to a considerable height above the sea and occupying large areas at the surface. Its thickness varies greatly, owing to the inequality of the surface on which it was

* Geology of Ipswich, pp. 63, 64.
† *Ibid.*, p. 65.
‡ Reproduced from *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 75, through the kindness of the Council of the Geological Society.

deposited. At Sutton Coralline Crag rises to a height of about 60 feet, and probably formed an island in the Red Crag sea, while close adjoining the Red Crag descends to the present sea-level. Mr. Dalton remarks that but little of the Red Crag east of the Deben is decalcified, its shells being retained even on the water-shed.*

The Coralline Crag outlier at Sutton has already been mentioned in the chapter describing that formation, but it still remains to notice the denudation that it underwent before the newer strata were deposited. It will be necessary for this purpose to make free use of Prof. Prestwich's description, for he undertook a special survey of this area, and was able to examine sections now quite hidden or much obscured.†

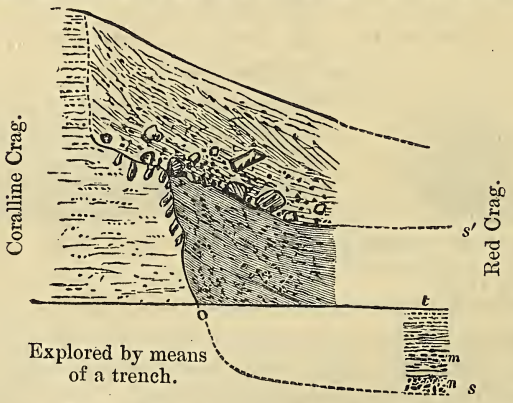
The reef or island of Coralline Crag is about a third of a mile across, and is overlapped on every side but the south by Red Crag, which abuts against a series of low vertical cliffs or steep slopes. On the south the Coralline Crag may have been continuous till comparatively recently with the isolated mass at Ramsholt, for the narrow valley that now separates them is of modern date.

The Ramsholt outlier is also overlapped by Red Crag, except towards the north, and perhaps to the north-west towards Waldringfield. The three sections now reproduced will illustrate better than any description the relation of the two deposits in the hill at Sutton.‡

FIG. 17.

Section in the Bullock-yard Pit, Sutton, 54 feet above Low-Water Mark.

Vertical scale of Figs. 17, 18, 19, about 12 feet to an inch.



t. Floor of pit 31 feet above Low Water Mark.

s^1. Upper shore-line, with blocks of Coralline Crag, flints, coprolites and shells.
m. Seam of shells of *Mytilus edulis*, almost all with both valves.
n. Bed of coprolites and large flints.
s. Lower shore-line.

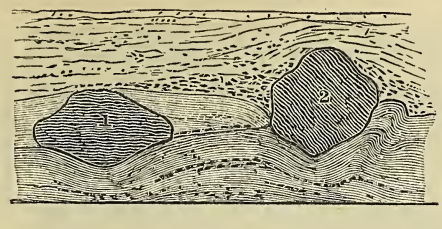
* *See also* Geology of Ipswich, p. 67.

† *Quart. Journ. Geol. Soc.*, vol. xxvii., pp. 116–119, 339–341, and pl. vi. (1871.)

‡ Reproduced from *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 340, by the kindness of Prof. Prestwich and the Council of the Geological Society.

Fig. 18.

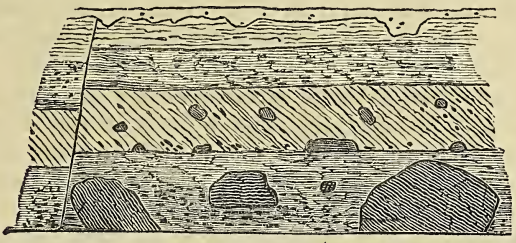
Section in the same Pit, but at right angles to Fig. 17.



Red Crag with two large blocks of Coralline Crag, the larger may weigh more than a ton. 1 must have fallen before and 2 after the deposition of the bed *r*. There were also many smaller blocks, some bored by Annelids, others covered with *Balani;* as well as flint-pebbles, coprolites, and unworn flints.

Fig. 19.

Section in the Pit near the Barn, at the Western Part of the Ridge.



Red Crag with many blocks of Coralline Crag, and here and there flints and phosphatic nodules. Showing the section of the lower shore on the western side of the reef. "The occurrence of these transported blocks of Coralline Crag is peculiar to these pits."

The occurrence of an eroded and bored surface of Coralline Crag at the Bullock Yard pit was first pointed out by Lyell, who, as far back as 1839, speaks of a buried cliff eight or ten feet high and in places slightly overhanging.*

Prof. Prestwich's further observations "show that there are two submerged cliffs, that they pass round the hill, and that the mass of Coralline Crag, forming the higher part of the hill, has been an old reef in the Red Crag sea."† The section in the Bullock Yard pit was still open when I last visited it, but the old cliff was becoming much obscured by talus and rain-wash. The Red Crag in this pit is of the usual character, and is referred by S. V. Wood to the upper division of the Red Crag, or to the same zone as the Crag at Butley.

Prof. Prestwich has figured a section at Ramsholt, showing erosion of the lower beds of the Red Crag before the deposition of those above; this also is here reproduced, through the kindness of the Council of the Geological Society (Fig. 20).

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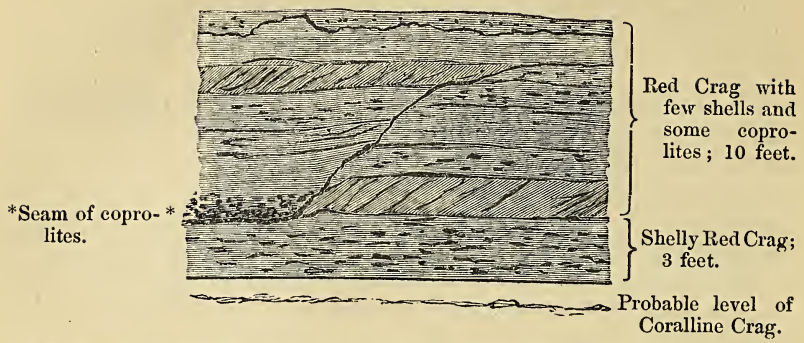
* *Mag. Nat. Hist.*, vol. iii., p. 314. (1839.)
† *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 339. (1871.)

Fig. 20.

*Section in the Red Crag at Ramsholt.**

(Prestwich.)


*Seam of coprolites.
*
Red Crag with few shells and some coprolites; 10 feet.
Shelly Red Crag; 3 feet.
Probable level of Coralline Crag.

The south-western part of the cliff at Bawdsey exhibits some of the clearest sections of the Red Crag and is one of the best places for collecting. It must not be forgotten, however, that here, as is always the case in the Red Crag, a hasty visit will only produce some twenty or thirty species, the others being rare, and only discovered after long search. Bawdsey, an inconvenient place to reach, and is perhaps best examined from Felixstow—there is a Ferry across the mouth of the River Deben. North of Bawdsey there are no more cliffs for several miles, the coast line being occupied almost entirely by the Alluvium of the River Ore, and by shingle beaches.

The next sections of interest are those exposed at different times in the coprolite works on the marshes of the Butley River, near Boyton and Butley. Here the Nodule Bed is found beneath the Alluvium, and sections are only visible while the pits are actually being worked, for at other times they are full of water. A large number of shells is obtained here, but as the Nodule Beds of the Coralline and Red Crag are both found, and are scooped out of the water and mixed in the works, it is impossible to say which species belong to the one formation and which to the other. Besides this the base of the Red Crag is undoubtedly full of derivative Coralline Crag shells, and we have the additional complication, first pointed out by S. V. Wood, that there is a constant tendency for the Red Crag itself to be partly eroded and its shells to be re-deposited on a slightly higher zone. The Butley fauna may thus be leavened with derivative shells from every horizon between the base of the Coralline Crag and the upper Red Crag. The contemporaneous shells of these pits are probably the northern and arctic forms, but *Cassidaria* and other Mediterranean species occur in such a perfect state of preservation that it is impossible to separate them. *Voluta Lamberti* is abundant, as are *Cardita senilis* and *Astarte Omalii*, both of which are probably only present in the Red Crag as derivative fossils from older strata.

* *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 327. (1871.)

The numerous Crag pits around Butley are all similar in character. They show false-bedded sand full of broken shells and rarer perfect specimens. The sand varies from buff to deep-red, or even purple, and is sometimes current-bedded at the highest possible angles. The whole of these pits show ferruginous banding, and often vertical rods of limonite in root-like forms are also seen. Many of the joints are filled with carbonate of lime. The upper part of the Red Crag, both here and at Chillesford, is buff and more like the Norwich Crag.

The well-known Crag pit, a quarter of a mile east of the Oyster Inn, at Butley, has been extensively worked by Mr. A. Bell, who has published the following section* :—

Section of Pit on the Neutral Farm, Butley.

1. Drift sand, black, full of small particles of quartz, with a large number of rolled stones [Rainwash].
2. Red sand, passing into
3. Yellow sand, then into
   Red sand. A large mass of brownish clay (full of casts of common mussel and *Trochus cinerarius*) at one part.
4. Vein of fine white sand, extending rather more than half-way across the pit.
   "These sands [2, 3, 4,], etc. are about 18 to 20 feet thick, and are nearly, except where in contact with the Crag, *totally devoid* of organic remains. Finely comminuted shells occur at the lines of junction."
5. Red Crag full of shells.
6. Red Crag ,, ,,
7. Unfossiliferous sand, partly false-bedded at top, separating 5 and 6 [? both over and under 5, over 6 in the figure given].
8. Line of freshwater shells.
9. Red Crag with shells. "A series of layers of fine sand and shells, having a rapid dip, being the lowest deposit seen."
   "The cross section [nearly at right angles] gives traces of considerable erosion."

A list of 192 species of shells from the Crag at Butley is given in Mr. Bell's paper, and the author speaks of the Butley Crag as a shallow-water deposit of upper Crag age. The land and freshwater shells from Butley, unlike those of Walton, are all living British forms† ; the rest of the land fauna is still almost entirely unknown.

North of the Butley River we find Red Crag abutting against or wrapping round a high reef of Coralline Crag, exactly as it does at Sutton; but great part of the sand is decalcified, and it will only be necessary to allude to two of the sections near Sudbourn, which have clearly shown the junction.

Mr. Dalton remarks that "there seems to be some error in the designation of the locality given by Prof. Prestwich to the section shown in Fig. 21, as there is no trace of a pit at that point, and the Chillesford Clay there separates the Glacial sand

* *Geol. Mag.*, vol. viii. pp. 450–455. (1871.)

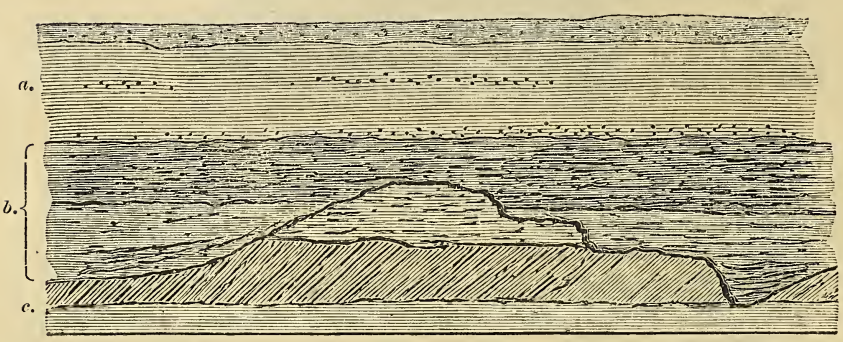
† R. G. Bell.—Land Shells in the Red Crag. *Geol. Mag.*, dec. 3, vol. i. pp. 262–264. (1884.) Wood records two arctic forms of *Limnæa*, but the determinations seem to be very doubtful.

from the Red Crag. If for $1\frac{1}{4}$ we read $\frac{3}{4}$, there is a pit which might have once shown such a section: an irregular junction of the Red and the Coralline Crags."

Fig. 21.

Section in a Pit by the Side of the Road $1\frac{1}{4}$ ($?\ \frac{3}{4}$) mile N.N.E. from Sudbourn Church.

(Prestwich. *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 335.)



a. Light-coloured sands with fine gravel.
b. Ferruginous and yellow sands (Red Crag).
c. Coralline Crag.

A good section of the junction of the two deposits can still be seen in the third Crag pit (marked on the Map), north-east of Sudbourn Church. Here the Red Crag is very shelly, *Mactra ovalis* and *Mya truncata* being particularly abundant.

We now enter the debatable land, where higher fossiliferous zones are met with, and there seems to be a distinct passage upwards from Red Crag to Chillesford Clay. The thickness of the Crag becomes also much greater, we lose the derivative fossils which have caused so much complication, and the beds become lighter in colour and more estuarine in character. The remainder of the Red Crag, and the Norwich Crag, will be described in the next chapter.

As no representatives of the zones remaining to be described have yet been found in Belgium, this may be a convenient place to speak of the strata which crop out on the eastern margin of the Anglo-Belgian basin. The Red Crag being in all probability perfectly continuous under the bed of the North Sea, the strata seen in England and Belgium must be merely the littoral deposits of the two sides of the same narrow sea. Under these circumstances, if the Red Crag and the Scaldisian are contemporaneous we might expect a very close correspondence in their faunas.

The upper part of the sands seen in the different excavations around Antwerp belongs to the Scaldisian* formation, and rests on a slightly eroded surface of the older beds, the junction being

* So named after the river Scheldt (the classical *Scaldis*) on which Antwerp is situated.

marked by a line of pebbles. In lithological character this division, like the Diestian sands, is a fine glauconitic sand, usually somewhat reddish, and full of shells. The Scaldisian molluscan fauna, of which a full list is given in the Appendix, now includes nearly 200 species, leaving out of account those of which the true horizon has not been satisfactorily fixed. Nearly all of these are also found in the Red Crag, but there is an entire absence of the arctic forms so conspicuous in the upper part of that formation. We may therefore, consider the Scaldisian of Antwerp to represent the Walton Crag of Suffolk, for it has a similarly southern facies. The deposits met with in a deep boring recently made at Diemerbrug, near Amsterdam, are more difficult to understand, for the fossils have a decidedly more northern character than those from the Scaldisian of Antwerp, and several arctic forms occur even at a depth of 1,000 feet. This boring will be more fully described at p. 220.

While engaged in writing these notes on the Belgian Pliocene beds, I received from Mr. G. Vincent a paper* in which special attention is drawn to a line of pebbles and erosion seen in the Scaldisian of the new docks at Antwerp. In this pebble-bed Messrs. Vincent and Delheid have discovered fragments of antlers of two species of Deer, a phalanx of Rhinoceros, bones of Birds, several specimens of *Helix nemoralis* (*H. Haesendoncki*, Nyst), and some fir-cones. This is the first time that land-mammals have been found in the Pliocene beds of Belgium, and the discovery is particularly interesting as helping to fill up the gap in our knowledge of the land-fauna of the Red Crag period. We know scarcely anything of the land-animals of that period, nearly all the specimens having been found in the Nodule Bed.

This mammaliferous gravel is the base of the sands which Messrs. Cogels and Van den Broeck have named "sables à Corbules,"† and which Messrs. E. and G. Vincent afterwards called "sables à *Corbulomya complanata* et à *Ophicardelus pyramidalis*," from these species being confined to the horizon, and therefore more characteristic.

Above the line of gravel there is a change of the fauna, several well-known species of the English Crag appearing for the first time and others becoming much more abundant. But there are no additional arctic species in these Corbula beds, except *Trophon despectus*, and the fauna is still that of the Red Crag, more closely allied to the lower portion than to the upper.

* Documents relatifs aux Sables Pliocènes à "Chrysodomus contraria" d'Anvers. *Bull. Soc. Malac. Belgique*, vol. xxiv. pp. xxviii—xxxv. (1889.)

† Observations sur les Conches Quaternaires et Pliocènes de Merxem, près d'Anvers. *Ann. Soc. Malac. Belgique*, vol. xii. pp. 68–74. (1877.)

CHAPTER VII.

RED CRAG—*continued*, NORWICH CRAG, AND CHILLESFORD CRAG.

Taking up the description of the Crag at the point where it was left at the end of last chapter, we find higher fossiliferous zones appearing north of the Butley River. The most southerly of the sections, those at Chillesford, were discovered by Prof. Prestwich* during an excursion made for the purpose of ascertaining "whether the distinction of age introduced upon palæontological grounds, between the crags of Norfolk and Suffolk, could be confirmed by visible superposition." More recently Prof. Prestwich has re-examined the pits, and the following notes are principally taken from his account.†

The sections at Chillesford are three, two of them close to the Church, and the third in a brick-field half a mile to the east-north-east. The pit behind the Church and that in the stack-yard below the Church, furnish an almost continuous section, Prof. Prestwich having proved by excavation the nature of the few feet of beds between the floor of the upper and the top of the lower pit. It must, however, be borne in mind that the latter pit is exposed to decalcification, from which the beds seen in the higher are exempt, for they are protected from the action of percolating water by an overlying mass of clay. The section exhibited by these pits is shown on the opposite page. (Fig. 22.)

The great interest in this section is that in the upper portion of the sand we find the Mollusca with their valves united and evidently on the spot where they lived. These tranquilly deposited strata pass upwards, without a break, into the Chillesford Clay, and downward into the "Scrobicularia Crag" of S. V. Wood, which is probably a continuation of the Norwich Crag of Norfolk. About six furlongs to the east-north-east there is a sand-pit (marked on the Map) which S. V. Wood considers also to show this "Chillesford Crag,"‡ and from these two pits he has collected a large number of mollusca. Northern shells are there much more abundant than in the lower beds, both in species and individuals, and a number of the common Red Crag forms seem to have disappeared. The three species of *Tellina*, *T. lata*, *T. obliqua*, *T. prætenuis*, so conspicuous around Norwich, occur in profusion.

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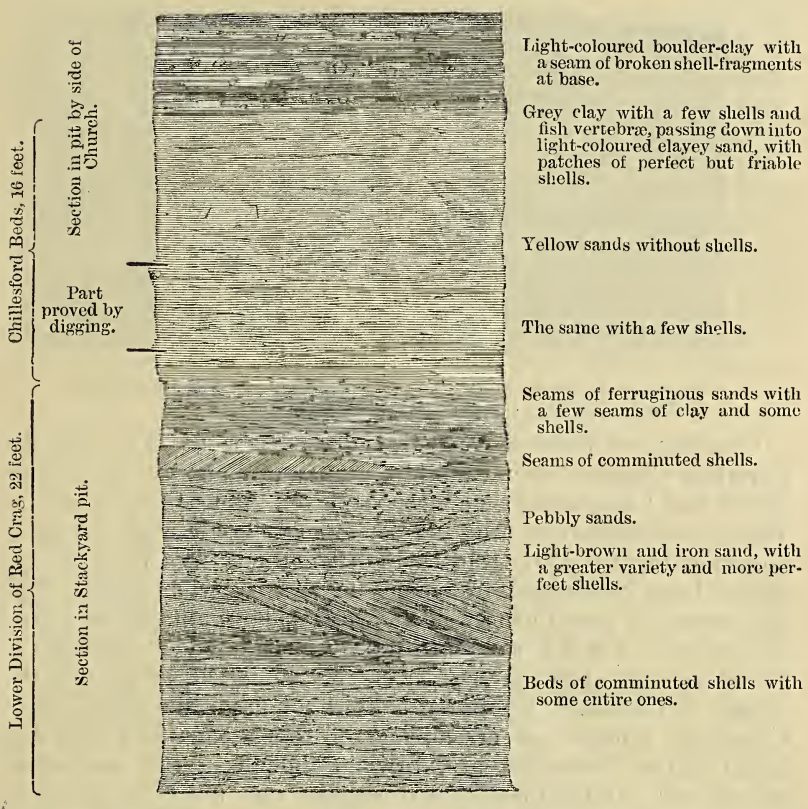
* *Quart. Journ. Geol. Soc.*, vol. v., pp. 345–353. (1849.)
† *See also ibid.*, vol. xxvii., pp. 335–339. (1872.)
‡ *Ibid.*, vol. xxii., p. 544. (1866.)

The brickyard half a mile east of the Church is in Chillesford Clay, and will be described in the next Chapter.

Fig. 22.

Section at Chillesford.

(Prestwich. *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 336.)


Chillesford Beds, 16 feet.
Lower Division of Red Crag, 22 feet.
Section in pit by side of Church.
Part proved by digging.
Section in Stackyard pit.
Light-coloured boulder-clay with a seam of broken shell-fragments at base.
Grey clay with a few shells and fish vertebræ, passing down into light-coloured clayey sand, with patches of perfect but friable shells.
Yellow sands without shells.
The same with a few shells.
Seams of ferruginous sands with a few seams of clay and some shells.
Seams of comminuted shells.
Pebbly sands.
Light-brown and iron sand, with a greater variety and more perfect shells.
Beds of comminuted shells with some entire ones.

Between Chillesford and Thorpe, where Norwich Crag appears, the Rev. O. Fisher* has traced a series of pits in which are found beds with *Mya* in the position of life. He also refers the shelly sands overlying Coralline Crag, seen in the pit three-quarters of a mile north-east of Sudbourn Church (*see ante*, p. 98) "to a shoal-deposit derived from the Mya-bed" (= Chillesford Crag), on the ground that while "many of the commoner shells of the Red Crag are at this place rare or altogether absent, those of the Mya-bed are in profusion."

The cliffs at Aldborough are now built over and sloped, but the Crag is seen in pits in the neighbourhood, and is very shelly, being protected from decalcification by the overlying Chillesford Clay. Prof. Prestwich observes that the upper division of the

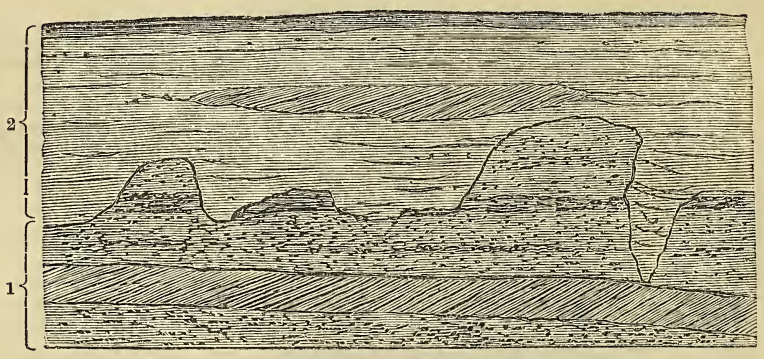
* *Quart. Journ. Geol. Soc.*, vol. xxii. pp. 19–28. (1866.)

Red Crag here rests on an eroded surface of the lower division, as is the case at Ramsholt. (Fig. 23.)

Fig. 23.

Section in Ballast-pit, Aldborough.

(Prestwich. *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 335.)



2. Brown Sands, with few shells and pebbles: upper division, 10 feet.
1. Shelly Red Crag: lower division 10 feet.

Crossing the marshes of the Hundred River we find that the Coralline Crag has entirely disappeared, and that the lower part of the Red Crag is also below the sea-level. Thus the pits around Thorpe are entirely in beds corresponding closely with the more estuarine deposits of the Norwich district, and the Crag here has always been considered to belong to the Norwich Crag. The best section is seen in the well-known "Aldborough Thorpe Pit" of geologists, which lies close to the southern edge of Aldringham Common and about three-quarters of a mile north-west of the village of Thorpe.* The Crag is light-coloured, like the Norwich Crag, and contains an assemblage of fossils identical with that found in the lower bed at Norwich, though in the number of individuals Arctic species are perhaps not quite so common. Prof. Prestwich gives a list of 28 species of mollusca from this pit, all of them occurring also at Norwich.

In Thorpe Cliff there is now no section of the Crag, and from Thorpe northward to Sizewell Glacial beds extend below the sea-level. "At Sizewell the Crag rises well above the beach and the inland marshes, and is exposed in several pits. One of these, at the northern end of Sizewell Cliff, about 200 yards inland, is in very shelly sand (of littoral and estuarine character) mostly white, but somewhat ferruginous above, and containing many bands and lenticular masses of limonite . . . . Similar Crag is met with in Sizewell Gap and half a mile west of it."† Other

* It may save confusion to point out that there are several places called Thorpe in Norfolk and Suffolk, and that two of the best known Norwich Crag sections are respectively at Thorpe near Norwich, and Thorpe near Aldborough.

† Whitaker, Geology of Aldborough, &c. (*Memoirs of the Geological Survey*), p. 25.

sections occur at Sizewell, but the base of the Crag has not been reached, though sunk rocks of Coralline Crag are found about a mile from the shore. Prof. Prestwich records 20 species of mollusca from a well at Sizewell, and notes the occurrence with them of fragments of Coralline Crag—probably showing that the upper sands overlapped the older Red Crag, and abutted against the ridge of Coralline Crag. The Chillesford Clay is cut out by later deposits in this neighbourhood, and the immediately underlying Chillesford Crag has not been recognised.

Continuing northward along the coast, there is now a gap of over two miles, occupied by the Alluvium of the Minsmere Level. Immediately north of this, where the cliff recommences, near Dunwich, Norwich Crag has been discovered by Messrs. Crowfoot and Dowson, who give a list of 44 species of mollusca, obtained principally from an exposure between tide-marks. "Mammalian remains were also found, and these appeared to come from a hard ferruginous bed of clay and sand, shown here and there on the beach, some feet below the shell-bed in the cliff."* As this is the most southerly locality from which a large and typical Norwich Crag fauna has been obtained, Messrs. Crowfoot and Dowson's list is here quoted. The arctic and also the estuarine character of the fauna is very marked.

Fossils from the Crag at Dunwich.

(Identified in all doubtful cases by S. V. Wood.)

c. Common. r. Rare.
v. c. Very common. v. r. Very rare.
a. Abundant.

Astarte compressa	r.	Cerithium tricinctum	v. c.
——— sulcata	v. r.	Helix hispida	v. r.
Cardita (derived?)	v. r.	Hydrobia ulvæ	c.
Cardium edule	a.	Littorina littorea	a.
——— grœnlandicum	v. c.	——— rudis	r.
Corbicula fluminalis	c.	Melampus pyramidalis	c.
Corbula striata	v. c.	Natica catena?	c.
Cyprina islandica	a.	——— clausa	r.
Leda oblongoides	r.	——— helicoides	r.
Loripes divaricatus	v. r.	Paludina media	c.
Lucina borealis	v. a.	Purpura lapillus	a.
Mactra arcuata	v. r.	Ringicula ventricosa?	r.
——— stultorum	r.	Scalaria sp.	v. r.
——— subtruncata	v. c.	Trophon antiquus	r.
——— truncata	c.	——— ———, var. contraria	v. r.
Mya arenaria	a.	——— gracilis?	v. r.
Mytilus edulis	c.	Turritella terebra	r.
Nucula Cobboldiæ	c.		
Pecten opercularis	c.		
Scrobicularia plana	v. c.	Fish bones.	
Solen siliqua	a.	Arvicola (teeth).	
Tapes virgineus	v. c.	Bos.	
Tellina lata	a.	Cetacea.	
——— obliqua	a.	Cervus.	
——— prætenuis	a.	Elephas.	
		Equus.	
Calyptræa chinensis	v. r.	Rhinoceros.	
Cancellaria viridula?	v. r.		

North and west of Dunwich there is an area of a good many square miles occupied by pebbly gravel, and by sands without

* *Proc. Norwich Geol. Soc.*, vol. i. part III. pp. 80–83. (1879.)

fossils. The relation of both these divisions to the shelly Crag is somewhat uncertain, for the only place where Chillesford Clay occurs, is on the border of the Marsh, one and a half miles north-west of Dunwich. Here the low position of the Clay suggests that the Crag in the surrounding area may be entirely below the level of the sea. The beds are fully described by Mr. Whitaker,* who considers the lower portion (the unfossiliferous sand) to belong to the Crag and the upper to strata overlying the Chillesford Clay, but in the absence of clear stratigraphical evidence and of fossils, it will perhaps be best to leave the description of the obscure area between Dunwich, Westleton, and the River Blyth for a later Chapter, and to keep at present to the undoubted Crag.

In a northerly direction the nearest fossiliferous section to that in Dunwich Cliff was found in a well made in 1887 at Southwold Waterworks, where also the total thickness of the beds has been proved. This section is of so great interest that the account is here copied, but the fossils obtained were not sufficient to allow of any separation of the different horizons. Small shelly exposures were also seen in the cliff north of the town, at a pit on the Lowestoft Road, and at Southwold Station. The two latter have been referred to the newer "Pebbly Series," but if this is correct they show that the "Pebbly Series" here contains a fauna identical with that of the Norwich Crag. All of the species determined are Norwich Crag forms, and *Tellina balthica*, so abundant in the higher division at other localities, is missing.

Well at Southwold Waterworks. 1886, 1887.

About 40 feet (? more) above Ordnance Datum.

Made and communicated by Messrs. Legrand and Sutcliff. (Notes from an examination of specimens, on the spot.)

		Feet.
Pebbly Series.	Ballast	37
Crag, 147 feet.	Dark yellow (red) sand	8
	Dark yellow, sand (with shells, stained red, *Cardium edule?*, *Cyprina islandica*, *Littorina rudis*, *Melampus pyramidalis*)	33
	Dark yellow (red) sand	6
	Light-yellow sand with black pebbles (flint and hard veined grit) and shells (*Mya truncata*, *Tellina obliqua*, *Littorina littorea*)	6
	Light-grey (silty) sand (full of mica)	18
	Light-greenish blowing sand (the colouring matter seems to be small grains of phosphate, and not glauconite)	56
	Light-greenish loamy sand, with shells (*Pecten opercularis*, *Natica*, etc.)	2
	Dark stiff clay (hard, brown)	10
	Grey loamy sand and shells (sandy silt, with worn shell-fragments. (*Balanus crenatus?* *Salicornaria crassa*, etc.)	8
London Clay		68½
Reading Beds		70½
Chalk		256
		579

* Geology of Southwold, and of the Suffolk Coast, (*Memoirs of the Geological Survey*). (1887.) This Memoir contains a folding plate of sections of the coast between Dunwich and Covehithe.

The greenish colour of the sand and the hardness of the fossils in the lower part of the Crag is very marked. These characters are always found when the strata are met with at depths beyond the reach of percolating surface water. The buff or red colour of ordinary sections of Crag is misleading; unweathered Red Crag is green or bluish. While on this subject it may be well to note a very similar section at Saxmundham, recorded by Mr. Dalton.*

Well at Messrs. Waller's Brewery, Saxmundham.

(Water rises to 12 feet from surface.)

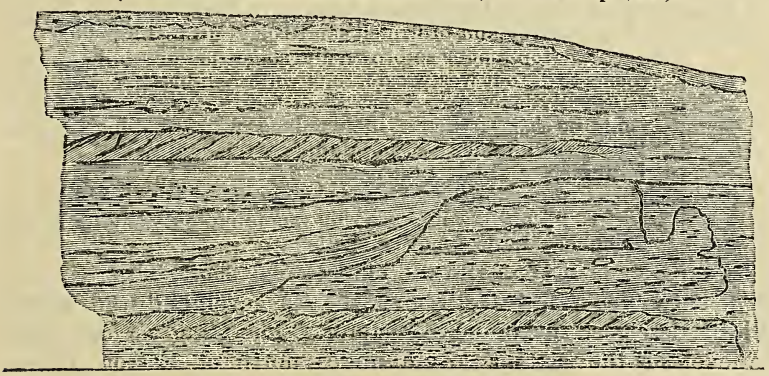
		Feet.
Red Crag, 105 feet.	Sand - - - - - -	80
	Red Shelly Crag - - - -	6
	Bluish-black Crag - - - -	19
	To Reading Beds -	105

The well-known "Bulchamp Pit" lies about four miles due west of Southwold. The section there is now overgrown, but the pit was so interesting that Prof. Prestwich's† account has been reproduced. He observed that "some years since, a section nearly 20 feet deep was well exposed." (Fig. 24.)

Fig. 24.

Pit near Bulchamp Union.

(Prestwich. *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 344.)



"In appearance and colour the pit is precisely like a Red-Crag pit; and it will be observed that we have here a repetition of the marks of erosion which we have noticed between the two divisions of the Red Crag in the Sutton district; or it may only be an eroded shoal in the lower division, as at Ramsholt" (*see* pp. 95, 96). The list of fossils, however, shows no trace of any horizon below the Norwich Crag, the 46 species mentioned by Prof. Prestwich being all Norwich Crag forms, and including

* Geology of Alborough, &c. (*Memoirs of the Geological Survey*), p. 53.
† *Quart. Journ. Geol Soc.*, vol. xxvii. p. 344. (1371.)

many land and freshwater mollusca rare or unknown in the older deposits. The level of this pit is little above that of the River Blyth.

The sections in the higher part of the Valley of the Blyth call for no remark, being almost entirely unfossiliferous, though a few shells have been found at Halesworth.

West-north-west of Southwold shelly Crag is seen in numerous exposures bordering on the marsh on each side of the Wangford Valley, and the pits have yielded, besides the common marine shells, land and fresh-water species, and mammalian bones and teeth. Lyell,* the Rev. O. Fisher,† Mr. G. Maw,‡ and Prof. Prestwich§ have all described sections in this valley, and a very full account of them is given by Mr. Whitaker.‖ More recently Mr. R. E. Leach has made extensive collections here, and has sent me a list of the species obtained. They are all Norwich Crag forms and among them is the *Cyrena* (*Corbicula*) *fluminalis*, found also by Lyell in this neighbourhood.

In the next valley to the north—that of Easton—there is only one pit in which shells occur, but the outcrop of the Chillesford Clay is so continuous that there is no doubt as to the Pliocene age of part of the sands which border the Marsh for a considerable distance. The "Yarn Hill Pit," so well-known to geologists, is not marked on the Map, but is situated on a small peninsula on the north side of the Marsh, half a mile west of Potter's Bridge and a mile and a quarter west-north-west of Easton Bavent, The section seen by Mr. Whitaker in 1878 was as follows¶ :—

A little pebble-gravel, at the highest part, up to 2¾ feet.
Chillesford Clay.—Grey and brownish sandy clay, up to 15 inches.
Crag. { Sand : the top foot or so brown and somewhat gravelly, but this seems to die out westward : then yellowish-brown or buff, with a gravelly layer 4 or 5 feet down (on the west only, as far as could be seen); then a little mixed white and black (with light-brown under at the middle part)—in all 7 to 9 feet, not bottomed at the deepest part.
Shelly Crag, some 2 feet shown, towards the west, under the white and black sand. In this was found only one *Corbicula*, amongst a host of marine shells.

At the foot of Easton Bavent cliff similar shelly Crag is seen, but it only rises a few feet above the sea level, and the section will be described in the next Chapter. The Crag is lost below the level of the sea for several miles north of Easton Bavent and Yarn Hill, and to show the character of the fauna at the spot where the beds disappear, a list is given of the mollusca found at these two localities. S. V. Wood referred the shelly sand at Yarn Hill to the Fluvio-Marine Crag, and that at Easton Bavent to the Chillesford Crag, but there does not seem to be any sufficient reason for separating them, and they are both close

* *Mag. Nat. Hist.*, n. ser. vol. iii. p. 316. (1839.)
† *Quart. Journ. Geol. Soc.*, vol. xxii. p. 27. (1866.)
‡ *Ibid.*, vol. xxiv. p. 377. (1868.)
§ *Ibid.*, vol. xxvii. p. 345. (1871.)
‖ Geology of Southwold and the Suffolk Coast (*Memoirs of the Geological Survey*), pp. 12–14. (1887.)
¶ *Ibid.*, p. 15.

to the Chillesford Clay. The Yarn Hill list is mainly taken from manuscript notes communicated by Mr. R. E. Leach, a few species being added from Wood's Monograph and the papers by Prof. Prestwich* and the Rev. O. Fisher.† The Easton Bavent list is compiled from Prof. Prestwich's paper and Wood's Monograph.

Fossils from the Crag of Yarn Hill and Easton Bavent.

Y = Yarn Hill. E = Easton Bavent.

Actæon Noæ	Y	Trophon antiquus var. contraria	Y
—— tornatilis	Y E	Turritella terebra	Y E
Buccinum Dalei	E	Valvata piscinalis	Y
—— undatum	Y E	Voluta Lamberti	Y
Bulla alba	Y		
—— lajonkaireana	Y		
—— regulbiensis	Y	Abra alba	Y
—— truncata	Y	—— obovalis	E
Calyptræa chinensis	Y	Anomia aculeata	Y
Cerithium tricinctum	Y	Artemis lincta	E
Chemnitzia rugulosa	Y	Astarte borealis	Y E
—— acicula	Y	—— compressa	Y E
Helix arbustorum	E	—— sulcata	Y
—— hispida	Y	Cardium edule	Y E
—— pulchella	Y	—— grœlandicum	Y
Hydrobia subumbilicata	Y	—— nodosum	Y
—— ulvæ	Y	Circe minima	E
Limnæa palustris	Y	Corbicula fluminalis	Y E
—— peregra	Y E	Corbula gibba	Y E
Littorina littorea	Y E	Cyprina islandica	Y E
—— rudis?	Y	Donax trunculus?	Y
Melampus pyramidalis	Y E	Leda oblongoides	Y E
Nassa incrassata	Y	—— lanceolata	Y
—— granulata	Y	Lepton nitidum	Y
—— propinqua	E	Lucina borealis	Y E
—— reticosa	E	Mactra arcuata	Y E
Natica Alderi	Y	—— ovalis	Y E
—— catena	Y	—— solida	Y
—— catenoides	E	—— subtruncata	Y E
—— clausa	Y	Modiola modiolus	Y
—— helicoides	Y E	Mya arenaria	Y E
—— hemiclausa	Y	—— truncata	Y E
Paludina media	Y	Mytilus edulis	Y E
—— vivipara	E	Nucula Cobboldiæ	Y E
Planorbis complanatus	Y	—— tenuis	Y E
—— spirorbis	Y	Pecten opercularis	Y E
Pleurotoma bicarinata	Y	—— princeps	Y E
—— turricula	Y	Pholas crispata	Y
Pupa muscorum	Y	Pisidium amnicum	Y
—— umbilicata	Y	Saxicava arctica	Y
Purpura lapillus	Y E	Scintilla ambigua	Y
Ringicula ventricosa	Y	Scrobicularia plana	Y
Rissoa semicostata	Y	Solen siliqua	Y
Scalaria clathratula	Y	Sphærium corneum	E
—— grœnlandica	Y E	Tapes virgineus	Y
—— trevelyana	Y	Tellina fabula	E
Succinea oblonga	Y	—— lata	Y E
—— putris	Y	—— obliqua	Y E
Trochus tumidus	Y	—— prætenuis	Y E
Trophon antiquus	Y E	Thracia sp.	Y

* *Quart. Journ. Geol. Soc.*, vol. xxvii. pp. 345, 346. (1871.)
† *Ibid.*, vol. xxii. p. 26. (1866.)

Teeth of Mastodon, and other vertebrate remains have also been found at Easton Bavent, and at Yarn Hill Mr. Leach has recently obtained bones of sea-birds and teeth of the characteristic Upper Pliocene vole, *Arvicola intermedius*.

Along the coast north of Easton Bavent, Crag does not re-appear above the sea-level for many miles, but one of the trial-borings made on the beach at Pakefield touched red shelly sand at a depth of a few feet (see p. 135), but no determinable fossils could be obtained.

In the Waveney Valley shelly Crag is again met with between Bungay and Beccles, and is evidently of considerable thickness, though seldom rising above the level of the Marsh. One of the best known of the sections is found near Aldeby, in a brick-yard on the northern side of the Waveney, about a mile and a half north-north-east of Beecles (but four miles by road).* Here has been obtained the boreal fauna on which the separation of the Chillesford Crag from the Norwich Crag is founded; for all the sections of the so-called Chillesford Crag further south, including Chillesford itself, have produced either very few species, or an assemblage quite indistinguishable from that of the Norwich Crag. At Aldeby we find a marked increase in the number of individuals belonging to Arctic forms, but at the same time there are no additional boreal species, and the horizon can only be separated from the Norwich Crag by the disappearance of a few southern mollusca, and the preponderance of northern forms.

The sections seen at different times at Aldeby are fully described in the Memoir relating to the district,† and it will be sufficient to quote two, one measured in 1867 by Mr. Dowson and one seen in 1875–6 by myself. Mr. Dowson's section of the central part of the pit is as follows:—

Section of Aldeby Brick-yard.

		Feet.
	Warp	1
[Valley Gravel.]	Coarse gravel	2½
[Chillesford Clay.]	Loamy sand, with thick veins of laminated clay	7½
	Laminated clay	6¾
[Chillesford Crag.]	Sand without shells	¾
	N.B.—A large flint, ¾ cwt., mentioned by Mr. Prestwich, came from the sand about here‡	
	Shell bed	2
	Sand, with veins of clay and a few fragments of clay, to water level	4¼

A boring was made at the extreme east end of the section in 1867. Sand and Crag (fragmentary), and perhaps a few small

* First brought to notice by C. B. Rose. *Rep. Brit. Assoc.* for 1868, *Trans. of Sect.*, p. 77. *See also Quart. Journ. Geol. Soc.*, vol. xxii. p. 545. (1866.)

† Geology of the Country around Norwich (*Memoirs of the Geological Survey*), pp. 86–88. (1881.)

‡ *See Quart. Journ. Geol. Soc.*, vol. xxvii. p. 454.

seams of clay, were bored through to about 10 feet beneath the water level, and gravel was reached, which the boring-tool could not pierce.

In 1875–6 the pit had been cut further back into the hill, and I noted the following section, which seems to show the Pebbly Beds overlying the Chillesford Clay :—

		Ft.	In.
	Soil	1	0
	Valley Gravel	5	0
Pebbly Series.	Sand, with occasional seams of pebbles	4	0
Chillesford Clay.	Bedded loamy brick-earth	4	0
	Clayey ditto	6	0
Chillesford Crag.	Brown sand, with a line of *Tellina* 8 inches down, and another at 1 foot 6 inches	2	0
	Sand full of upright *Mya arenaria*	0	5
	Light brown sand with scattered shells	1	4
	Shell bed, *Astarte, Mactra, Cyprina,* &c., and occasionally large unworn flints	0	2½
	Band of blue clay	0	0½
	Loamy brownish sand	1	0
	Hard brownish brick-earth with scattered shells	2	0
	Sand	?	

One of the most marked peculiarities of the Aldeby pit is the constant occurrence there of bivalves in the position of life with the valves united. The absence of derivative fossils (except possibly *Pectunculus*) also makes it an important locality for deciding what was the true character of the contemporaneous fauna of the Chillesford Crag. This opportunity has been fully used by Messrs. Crowfoot and Dowson, to whose researches we almost entirely owe our knowledge of the fossils. The list now includes 66 species of Mollusca, air-breathers being exceptionally scarce and only represented by two or three species. We have also traces of Deer, Elephant, Horse, and Vole, besides the Walrus (*Trichechus Huxleyi*), the Dolphin (*Delphinus delphis*), and the Guillemot (*Uria troile*). A full list of the fossils will be found in the Appendix.

Again on the southern side of the Waveney, Crag was met with in two wells at Beccles Waterworks. Here the surface was respectively at 107 and 110 feet above the sea-level, the wells both reaching the Chalk at a depth of 157 feet. The following section is condensed from the account communicated by Mr. W. M. Crowfoot,* who examined all the samples :—

Well at Beccles Waterworks (1870–1.)

	Feet.
Soil	1
Chalky Boulder Clay	10¼
Middle Glacial Sands	17¾
Pebbly Series	33
Chillesford Clay (loamy sands)	15

* Geology of the country around Norwich (*Memoirs of the Geological Survey*), p. 156 ; *see also Proc. Norwich Geol. Soc.*, vol. i. pp. 76–79.

		Feet.
Chillesford Crag, 14½ feet.	Red coarse loamy sand, full of pieces of friable shells	3
	Loamy sand, no shells, occasional veins of indurated loam in red sand.	5
	White sand mixed with red. From 82 to 85 feet very shelly.	
	Veins of indurated loam in sand	6½
	Clean yellowish red sand, no shells	
Fluvio-marine Crag. 65½ feet.	Muddy silt, impervious to water. Has a marshy smell (shelly)	15½
	Muddy silt, mingled with dark slimy clay	3
	Muddy silt, (at 116 feet numerous pieces of broken shells occur)	24
	Clean sand	3
	Sand with numerous rounded nodules of clay to 137 feet	
	Clean sand	20
	To Chalk	157

On the evidence of the fossils the muddy silts and sands of the lower part of these wells were referred to the Fluvio-marine Crag by S. V. Wood, who determined 50 species of mollusca. The assemblage corresponds with that of Aldeby, but is perhaps not quite so arctic. Similar shelly sands have been reached in several other wells in the neighbourhood of Beccles.

West of Beccles the surface of the Chalk seems to keep at the same level for some distance, for at Geldeston about two miles from Beccles "white clay" (perhaps Chalk) was reached at about 60 feet beneath the river-level in an old well. The greater part of the beds are described as bluish sand, but I could not learn of any shells being found.

More recently (1888) Messrs. Isler & Co. have sunk a well at Broome Place, about two miles north-north-east of Bungay, which showed the following section :—

Well at Broome Place, Bungay.

		Feet.
	Sunk hole (no record)	10
Valley Gravel.	Ferruginous gravel and sand	30
Boulder Clay.	Yellow Clay	12
	Chalky Boulder Clay	20
Pebbly Series, 29 feet.	Flint-pebbles	9
	Flint-gravel, and sand	20
Norwich Crag, 48 feet.	Grey gravelly sand. *Mya arenaria, Balanus*, &c.	16
	Shell bed. *Mytilus edulis, Tellina obliqua, Mya, Cardium*	2
	Loamy sand and shells	2
	Grey sand	5
	Sand and shells. *Purpura lapillus, Balanus*	6
	Gravel and shells. *Turritella terebra, Pecten opercularis, Purpura lapillus*	4
	Coarse loamy sand. *Tellina obliqua*	6
	Fine sand and shells	7
	To Chalk	149

A sample of very shelly gravel marked 112–116 feet contained the following species:—

Chemnitzia internodula.
Natica catena.
Purpura lapillus.
Trochus.
Turritella terebra.

Astarte.
Cardium edule.
Corbula gibba.
Cyprina islandica.
Mactra ovalis.
Mya arenaria.
Mytilus edulis.
Nucula Cobboldiæ.
Pecten opercularis.
Pholas.
Scrobicularia plana.
Tellina obliqua (or T. lata).

Balanus crenatus (very abundant).

The shells are much rolled and waterworn, and indicate shallow water, though periwinkles and other species entirely confined to shores are rare.

Around Bungay shelly Crag has been seen at the surface at three points; in a small pit at Dukes Bridge; in the cutting at Bungay Station, where however it is now entirely hidden; and at the foot of Bath Hills. It has also been met with in three wells at Ditchingham, but none of these were carried down to the Chalk, and we have no means of ascertaining the total thickness of the Crag in this neighbourhood.*

Crag has been seen at several spots at the foot of Bath Hills, but during the survey of this district it could only be found in a pit in the kitchen garden at Ditchingham Lodge. It here consists of shingle and sand, mixed with shells, and contains the ordinary Norwich Crag fauna, with abundance of periwinkles—showing apparently the proximity of the shore. About 25 species of mollusca were found.

The well at Ditchingham Hospital was in similar, but apparently more sandy beds, and the shells came from a somewhat lower level. Among the fossils was a single columella of *Voluta Lamberti*, broken but not much worn, and of the same light colour as the contemporaneous fossils. Except a specimen from the Drift, found by Dr. S. P. Woodward, this is the only occurrence of the Volute in Norfolk, though it occurs in beds of the same age at Yarn Hill. The rest of the fossils were all common Norwich Crag forms.

Higher up the Waveney Valley, Crag reappears near Harleston Station, and Mr. Dalton mentions two sections with fragments of *Cardium*, *Cyprina*, *Tellina*, and *Turritella*; but possibly the strata represent the shelly condition of the so-called "Middle Glacial sands" so well seen near Beccles. About two miles to the west, at Needham, a well has lately been sunk to the Chalk, and the section and samples communicated by Messrs. Isler & Co. show that the Pliocene strata are here 95 feet thick. Of this mass the upper 25 feet consist of quartzite gravels without fossils (Pebbly Gravel); the underlying strata, down to the Chalk, are gravels and silty sands, with the common shoal-water Norwich

* Full descriptions of the sections in the Waveney Valley will be found in the Geology of the Country around Norwich (*Memoirs of the Geological Survey*) (1881), pp. 84–89.

Crag shells. Still further to the south-west Crag was again met with in a well at Hoxne Rectory, and appears to have been 60 or 70 feet thick; possibly in the Hoxne well only the deposits immediately above the Chalk belong to the Crag, but the exact depth from which the fossils were obtained is not mentioned.* The only fossil recorded is *Purpura lapillus* (many specimens). Two miles away Chalk crops out, and no overlying Crag is visible. The sudden rise of the Chalk immediately west of Hoxne, coupled with the common occurrence of the rock-loving *Purpura lapillus*, is suggestive of the existence in this neighbourhood of an old shore-line and buried Chalk cliff, against which the shelly Norwich Crag is banked. The great thickness of the Drift makes it impossible, however, to trace this old coast, though each year additional borings penetrate to the Chalk, and before long we may be able to fix the original limits of the Norwich Crag sea.

The Crag of the Waveney Valley is separated from the outcrops further north by a wide area occupied by later deposits, too thick to be often penetrated by wells. Where Crag reappears, the Chillesford Clay has become so impersistent and thin, and there is so marked a tendency for clay-seams to come on at various horizons, that Mr. H. B. Woodward, who examined in detail the typical area around Norwich, felt compelled to class together the whole of the deposits beneath the Lower Boulder Clay as Upper Crag or Norwich Crag Series. The following pages are mainly condensed from Mr. Woodward's account.†

The Upper Crag of Norfolk comprises a variable group of sands, pebbly gravels, and laminated clays, with occasional seams or patches of shells. Near Norwich and in the Bure Valley it has a general thickness of about 30 feet. The ordinary succession of the beds is as follows:—

4. Buff false-bedded sand and red gravel, formed chiefly of flint pebbles, with also pebbles of quartz and quartzite, and ironstone nodules. Veins and seams of laminated clay occur, and the gravel is occasionally cemented into a conglomerate or "Iron-pan." [This division has been called the Pebbly Sands and Pebble beds, the Bure Valley Beds, also the Westleton Beds.]
3. Laminated clay, with seams of sand and gravel; or clay and sand in thin layers rapidly alternating. [This division has been called the Chillesford Clay.]
2. White and brown sand with pebbly gravel and ironstone nodules. [This division, including also No. 1, has been separated into an Upper or Chillesford Crag, and a Lower or Fluvio-marine Crag.]
1. Bed of unworn and rolled flints, called the "Mammaliferous Stone-bed."

Chalk with flints.

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* Geology of Halesworth and Harleston (*Memoirs of the Geological Survey*), p. 38.

† *See also* Geology of the Country around Norwich (*Memoirs of the Geological Survey*), pp. 31–89.

The Upper Crag is exposed on the borders of the valleys of the Bure and Yare and their tributaries; in the Bure Valley it covers the larger extent of ground.

Shells are most abundant in beds 1 and 2. They are generally much comminuted, but sometimes entire and in their natural position. The bands of clay (3) have no doubt served in some instances to protect the shells from destruction by percolating water, for when these occur in the pebbly gravel (4) they are generally in the form of casts.

The impersistence of the shell-beds has been the subject of remark by almost every observer. In by far the larger number of sections of the Norwich Crag no organic remains have been found. In some pits where their former abundance has been testified to, they are now rare, or the seam has been entirely worked away. While on the other hand, pits at one time yielding no shells have now become fossiliferous. Hence considerable interest is attached to every pit that is being worked.

To its occasionally fossiliferous nature the Norwich Crag owes the attention it has received. The shells were so early as 1729 noticed by John Woodward in his celebrated Catalogue, and they were subsequently illustrated by Parkinson, William Smith, J. and J. De Carle Sowerby.

The earliest descriptions of the strata are contained in the writings of Arderon dating 1746, after which time they were not particularly noticed until, in 1823, R. C. Taylor gave a clear and excellent description of the beds, and first applied in a definite geological sense the term Crag, a word commonly used in Suffolk to designate any shelly sand or gravel.

Later, in 1833, the beds were described and many of the species were figured by Samuel Woodward; and in 1836 Mr. Charlesworth proposed the term Mammaliferous Crag to distinguish the Crag beds of Norfolk from the Red and Coralline Crags which he had previously separated. The term Norwich Crag was subsequently employed by Lyell in 1839.* Thus the terms Mammaliferous or Norwich Crag came into use, and as a rule they were taken to include the group of beds here considered as Upper Crag. The term Norfolk Crag was employed by John Phillips,† and Upper Crag by Mr. Godwin-Austen,‡ and Messrs. Wood and Harmer.§

Of late years the beds and fossils in the principal sections have been minutely examined and described, and it has been sought to establish divisions that have been made out in the so-called typical section at Bramerton, and to correlate divisions in other sections with them.

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* *Proc. Geol. Soc.*, vol. iii., p. 126.

† *Rep. Brit. Assoc.* 1863, Trans. of Sections, p. 85.

‡ *Rep. Brit. Assoc.* 1868; *Geol. Mag.*, vol. v., p. 475. (1868.)

§ *Rep. Brit. Assoc.* for 1868, Trans. of Sections, p. 80; *Geol. Mag.*, vol. v., p. 452. (1868.) The name Norwich Crag is not even used by Messrs. Wood and Harmer in their map of the Crag District.

Certain lithological characters and certain species of mollusca have been taken as guides in forming the subdivisions; but unfortunately the numerous observers have not only, as a rule, taken different views but have used different terms; hence there have been imported into the subject of the Pliocene deposits of Norfolk such a number of local names and synonyms that the literature is most confusing to the student.

Thus in 1865 Dr. J. E. Taylor pointed out the differences in the two shell beds exposed in the Crag on Bramerton Common. The upper bed contains a larger per-centage of northern mollusca, and the most abundant species in it belong to somewhat deeper water than those found in the lower division.*

Subsequently S. V. Wood, jun., correlated this upper bed of Crag with the Chillesford shell-bed above the Red Crag, and he paralleled a seam of brown clay which almost immediately overlies it, with the Chillesford Clay. The lower bed of Crag at Bramerton he regarded as the fluvio-marine equivalent of the upper portion of the Red Crag.

More recently Messrs. Wood and Harmer separated the fossiliferous pebbly sands and gravels of Belaugh, Wroxham, Crostwick, and other places in the Bure Valley from the Norwich Crag, regarding the occurrence in them of *Tellina balthica* (*solidula*) as an indication of their distinct age. And hence these pebbly sands came to be regarded by them as "Lower Glacial Sands," and (in 1866) to be called the "Bure Valley Beds."†

Still later Prof. Prestwich divided the beds into Norwich Crag, Chillesford Clay, and Westleton Shingle. He included most of the fossiliferous beds, whether with or without *Tellina balthica*, as Norwich Crag. His Westleton Beds are, in the district now described, generally equivalent to the Bure Valley Beds.‡

The Norwich Crag has been described as a variable group of sands, pebbly gravels, and laminated clays, with occasional seams or patches of shells. And this is not only true of the several sections, if, for instance, we compare those at Thorpe, Postwick, Bramerton, and Whitlingham, one with another, but it is equally true of the sections themselves, for as these are in course of time cut back for economic purposes, the sections vary continually, owing to the extensive false-bedding. None of the beds are persistent.

The attempted subdivisions and correlations have been made on lithological and palæontological grounds.

On lithological grounds the Chillesford Clay has been taken as an horizon. It has been described as a beautifully laminated clay, comprising in reality rapid alternations of clay and sand, both very micaceous. At Aldeby, Surlingham, Hartford Bridge, South Walsham, Hoveton (near Wroxham Railway Station),

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* *Geol. Mag.*, vol. viii., p. 314.

† *See Geol. Mag.*, vol. v., p. 455 (1868); vol. vi., p. 232 (1869); vol. vii., p. 20 (1870). *Quart. Journ. Geol. Soc.*, vol. xxii., p. 547 (1866). *See also Proc. Norwich Geol. Soc.*, vol. i., p. 50 (1878).

‡ *Quart. Journ. Geol. Soc.*, vol. xxvii., 1871, p. 452.

Coltishall, and Ludham, there are good "jambs" of clay,* from 3 or 4 to 15 or 18 feet in thickness. These possess almost identical characters. But at the "typical" localities of Thorpe, Postwick, and Bramerton, there is no conspicuous development of clay, and where seams are present they do not always possess the lamination said to be characteristic of the Chillesford Clay. One who visited the before-mentioned localities in succession would undoubtedly go away convinced that the Chillesford Clay was a well-marked horizon in Norfolk. But if he endeavoured to trace out these clays on the ground, noticing the intermediate sections, and the behaviour of the clays themselves, he would become convinced that while such laminated clays are *characteristic* of the Pliocene beds of Norfolk, they are not confined to one horizon, they were not all deposited at one particular time, and their absence is not necessarily the result of denudation.

The sections at Coltishall and Hartford Bridge, as well as those at Thorpe Hamlet, Hellesdon, and Hamlington, demonstrate that these clays are intimately connected by false-bedding with the pebbly gravels that often overlie them, and that they pass occasionally by interbedding in their horizontal extension into sand and gravel. In some sections we find two or more bands of clay, any one of which might on lithological grounds be termed the Chillesford Clay.

Turning now to the divisions based on organic remains, it is a fact that the two beds at Bramerton Common present some differences of local interest. But these two beds are merely separated by a few feet of false-bedded sand, which contains shells sparingly. And while the lower bed includes a larger assemblage of species, only three rare forms found in the upper bed have not been obtained in the lower. The lower bed has been termed by Lyell the Fluvio-marine Crag, because containing a mixture of marine, land, and freshwater shells, with bones of fishes and mammalia, it was clearly accumulated at the bottom of the sea near the mouth of a river. The influence of freshets is seen in the varieties and monstrosities of the Purples and Periwinkles (Fig. 25). But the deposit itself and the majority of the organic remains are so decidedly marine, that the term Fluvio-marine is rather apt to mislead. While numbers of freshwater shells from the Crag may be seen in Museums and private collections, they are exceedingly rare in the deposit. Borings of *Pholas* and marine Annelides occur in the Chalk at the base of the Stone Bed, and among the boulders and sometimes in crevices of the Chalk there occur,

Fig. 25.

Littorina littorea, distorted.

* The term "jamb" is applied to any impersistent, and generally lenticular mass of clay, marl, or brickearth—it is a bed "jammed between other strata."—(*Nall.*) Some of these beds of clay are shown on the Geological Survey Maps.

at Thorpe near Norwich, many specimens of *Pecten opercularis* and *Tellina crassa*.

The upper bed at Bramerton has been correlated with the seam of shells at Brundall, and with the Crag at Aldeby, Horstead, and Burgh near Aylsham. But the Crag of Horstead, Coltishall, Burgh, and that also of Belaugh ("Bure Valley Beds") is regarded by Messrs. Wood and Harmer as fluvio-marine in character.* Hence the application of the term fluvio-marine to the lower bed at Bramerton is as ambiguous as it is unnecessary, for as Mr. Goodwin-Austen has remarked, "the fluvio-marine portions of the Norwich Crag are simply the indications of the places where rivers discharged into the sea."†

Moreover from the fact that there is no hard line between the divisions made out at Bramerton, and that they are there connected by occasional shells through the intervening sand, there is nothing to show that the equivalent of this sand may not elsewhere be represented by a mass of shells. It cannot be said positively that the shell beds at Aldeby, Brundall, and Coltishall were formed precisely at the time when the uppermost Crag of Bramerton was laid down.

Comparisons have been usually based on the so-called typical section at Bramerton, where the uppermost zone shows the comparative abundance of the slightly deeper-water and more boreal forms, suggesting slow submergence attended by gradual alterations in the climatic conditions. Trifling indeed would be the alterations, for in number of boreal species the lower crag furnishes a larger list than the upper crag. The lower bed is conspicuous for the abundance of littoral shells.

The chief fossiliferous localities are Thorpe, Postwick, Bramerton, Whitlingham, and Brundall, in the Yare Valley; and Wroxham, Belaugh, and Coltishall, in the Bure Valley. To these may be added several other names of places now or formerly fossiliferous, Attlebridge and Catton, in the Wensum Valley; Hamlington, Little Plumstead, Kirby Bedon, Trowse, Arminghall, Lakenham, Shottesham, Forncett, Newton Flotman, Stoke Holy Cross, and Saxlingham Nethergate, in the valley of the Yare and its tributaries; Salhouse, Rackheath, Crostwick, Spixworth, Horstead, Stratton Strawless, Marsham, and Aylsham in the Bure Valley.

When we come to study the shells in the several beds of Crag, even those acknowledged to be on the same horizon, we find that they vary not only in the abundance of particular forms, but also in the number of different species, indicating perhaps slightly varying depths of water or diversities in the sea-bed, that influenced their distribution. At Brundall Station, for instance, *Nucula Cobboldiæ* is specially abundant. At Brundall Church, in a bed distinctly on the same horizon, this shell is rare, and perfect valves of *Cyprina islandica* are met with in profusion.

* Supp. to Crag Mollusca, p. 112 (1872); *Geol. Mag.*, vol. v., p. 452 (1868).
† *Quart. Journ. Geol. Soc.*, vol. vii., p. 129. (1849.)

At Blake's pit, Bramerton, *Scrobicularia plana* is abundant, though exceedingly rare in the adjoining pit on the Common. *Calyptræa chinensis* and *Loripes divaricatus* abundant in an adjacent lane-cutting, in Kirby Bedon parish, are not nearly so common in either of the pits at Bramerton. At Arminghall *Mactra ovalis* is so abundant that Dr. J. E. Taylor well observed that the deposit might be called the *Mactra* bed. In one pit at Wroxham, *Astarte borealis* is particularly common, *Tellina balthica* is rare; while at Belaugh the reverse is the case.

Although the term Mammaliferous Crag was applied by Mr. Charlesworth, from the occurrence in it of the remains of mastodon, elephant, deer, &c., yet these remains are so rare in the Crag that it falls to the lot of few collectors to obtain specimens themselves; and most of those which enrich our public and private collections were obtained from the workmen engaged in digging the Crag. Probably not more than twenty teeth of the Mastodon* have been obtained, but this form possesses peculiar interest from the fact that it has not at present been discovered in the Forest-bed Series.

It is the general opinion, and one confirmed by the testimony of the workmen, that the mammalian remains are most abundant in the lower portions of the Crag. Its basement bed consists of a layer of more or less rolled flints with a few pebbles of quartz and quartzite, embedded in a clayey or sandy matrix, and has been termed by Mr. Gunn the "Mammaliferous Stone Bed," from the fact that so many bones have been obtained from it.

The bones found at Thorpe, where Mr. H. B. Woodward has obtained numerous specimens, are, however, most abundant immediately *above* the Stone Bed, few occurring in it. During recent years the Crag has been extensively removed and the Stone Bed has been well exposed. On one occasion a portion of the tusk of an Elephant was found *on* the Stone Bed. Still the specimens are sufficiently near the Stone Bed to support the statement that bones are most abundant in the lower portions of the Crag, though Mr. Woodward does not consider that they have any special connection with the Stone Bed, or that this bed ought to be separated from the Crag.

Instances are on record of Mammalian remains having been obtained at some distance above the base of the Crag, as at Surlingham, where the tooth of a Mastodon was found by the workmen in a bed of sandy gravel just above the mass of laminated clay so largely worked. The exact spot from which this specimen was obtained was pointed out by Mr. Gunn, in 1873, who explained that the specimen showed signs of having been derived from some lower bed, for adhering to the tooth, were portions of a hard gravelly matrix, which was distinct from the

* Noticed by Parkinson (1811), Organic Remains, p. 449. A grinder of the Mastodon found at Whitlingham was figured, in 1816, by William Smith in his Strata Identified by Organized Fossils.

beds in which it was deposited. At Coltishall mammalian remains have been found in the pebbly gravel overlying the clay-beds.

The evidence shows that the bones may belong to the period as much as the shells which occur abundantly in the Stone Bed and in crevices of the underlying Chalk. Although perhaps comprising relics of some old land-surface destroyed during the formation of the Crag, it is hardly possible that the Stone Bed represents an ancient soil, or that any portion of the Chalk itself is an old land surface. At Postwick the surface of the Chalk, as is well known, is bored by marine shells and annelids; and at Bramerton the presence of Pholas-burrows has also been pointed out.

The Stone Bed is therefore part of the Norwich Crag. Its formation was very likely somewhat analogous to that of the coarse flint foreshores and sea-beds found near Cromer and Trimingham, where the flints are worked directly out of the Chalk. Hence it may be of slightly different ages as the Crag sea encroached further and further.

The Mastodon it is true indeed lived in earlier times than those of the Norwich Crag, and its remains might have become embedded in some previous freshwater or lacustrine deposit, whose destruction, as suggested by Mr. Harmer, yielded the remains found in our Norwich Crag; and yet it may have lived on to Newer Pliocene times, and remains of the animal, thrown on the beach, may have been in some cases rapidly covered up and preserved. From the state of preservation of the specimens in Mr. Fitch's collection, Mr. E. T. Newton was of opinion that they could not have been derived but belonged to animals that had lived in the Crag period.

A few of the more interesting of the sections in the Norwich area will be selected to illustrate the singular variability of the deposits, for though by taking particular pits as "types" we can subdivide the Crag into apparently well-marked zones, yet a series more truly illustrating the character of the Norwich Crag will show how impersistent are these zones, and how little reliance can be placed on mere lithological changes. It should not be forgotten also that the whole of the Pliocene strata of this district are essentially of shallow-water or littoral origin, and that such deposits, from the nature of their origin, must always be extremely variable.

Continuing to follow northward the exposures of the Crag we will take first the Valley of the Tese. Here Pliocene beds outcrop for a long distance, but most of the sections are of little terest and are sparingly fossiliferous. It will therefore only be necessary to mention one or two of them—the rest will be found fully described in Mr. H. B. Woodward's Memoir.

The most southerly of the fossiliferous pits in the Tese Valley occurs at Tharston Furze Hill, about one mile south of Flordon Station. Above the Chalk was seen the stone-bed, and this was

overlaid in one part by a bed of laminated clay, and a mass of buff and brown false-bedded sands, all belonging to the Crag Series. Bones have been found in the Stone Bed, and an elephant's tooth, identified by Mr. Gunn as *Elephas leptodon* (= *E. antiquus*, var.), was found in gravel about three or four feet above the Chalk, but may belong to a deposit newer than the Crag.

At Saxlingham Nethergate traces of shelly Crag with *Leda lanceolata* and *Turritella terebra* have been seen, and remains of Mastodon are recorded from one pit, but most of the beds seem to consist of unfossiliferous pebbly sands. Shells again occur immediately above the Chalk on the opposite side of the main valley, at Newton Flotman. Wood referred the shelly Crag at Saxlingham to the Chillesford Crag.

At Stoke Holy Cross the strata apparently become more fossiliferous, and in a pit situated about half way between the Church and the Mill Mr. H. B. Woodward noted the following section:—

		Feet.
Glacial drift		22
Upper Crag	Gravel and shingle	8
	Sand	2
	Laminated clay and sand	1 to 1½
	Shelly seam and stone bed, with bones of *Bos* and *Cervus*, *Trophon antiquus*, *Mytilus edulis*	1
Chalk with flints (16 feet shown).		

Shells have also been found in an old well at Stoke (S. Woodward, MS. 1825); the species being apparently *Littorina littorea*, *Purpura lapillus*, *Trophon antiquus*, *Cardium edule*, *Cyprina islandica*, *Mya arenaria*, *Tellina obliqua*, as well as bones of deer (?) and *Platax*.

Near Arminghall, and about half a mile south-east of Lakenham Bridge, the following section may be seen:—

		Feet.
Upper Crag	Sand and pebbly gravel	10
	Shell-bed	3 to 4
	Laminated clay	2
Chalk.		

The section at Arminghall is of interest in showing a bed of shells above a band of clay, which has been termed the "Chillesford Clay," and which rests upon the Chalk. Attention was drawn to it in 1869 by Dr. J. E. Taylor, who pointed out that the clay rested directly upon the Chalk, excepting the usual Stone Bed, and was capped by a bed containing Norwich Crag shells. The following is a list of the species obtained here by Mr. H. B. Woodward:—

Littorina littorea.
Natica, sp.
Purpura lapillus.
Cardium edule.
Cyprina islandica.
Mactra ovalis.
Mya arenaria.
Mytilus edulis.
Tellina obliqua.
——— prætenuis.

At Arminghall the Tese joins the Yare, and instead of immediately continuing the description of the beds around Norwich, we will first take the upper part of the Valley of the Yare.

The sections above Eaton and Cringleford show pebbly gravels in which no fossils appear to have been found, but both ferruginous casts and shells with the calcareous matter preserved occur at Eaton* At Hartford Bridge clay occurs in considerable thickness, and Mr. H. B. Woodward sketched the following section (Fig. 26), remarking that "the mode of occurrence of the clay and sand proves the intimate connection of the deposits, for not only does the clay contain lenticular patches of pebbly sand, but itself forms a great mass, false-bedded with the overlying sand and gravels. No such a mass of clay is seen in the adjoining pit at Eaton where Crag shells have been found. This wedge-shaped mass is about 20 feet in length."† Fragments of mammalian bone have been found in the sand and shingle (bed 1) beneath the laminated clay.

Fig. 26.

Section at Hartford Bridge.

(H. B. Woodward.)

		Feet.
Upper Crag	4. Pebbly gravel - - - -	10
	3. Wedge of pebbly gravel (three feet) -	
	2. Laminated clay, with nests and veins of sand and fine gravel dovetailing into the pebbly gravel - - -	5
	1. Sand and shingle - - -	4 to 6
A. Chalk.		

The Pliocene strata outcropping in the Valley of the Wensum west of Norwich consist mainly of pebbly sands, with traces of laminated clay, but nearly always without fossils. Around Norwich itself sections are so numerous that we can here only allude to a few of the more interesting ones, all of which lie in the Valley of the Yare between the city and Surlingham. The other sections are described in Mr. Woodward's Memoir (*op. cit.*)

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* Lyell, *Phil. Mag.*, 1839, p. 260.

† Geology of the Country around Norwich (*Memoirs of the Geological Survey*) p. 69.

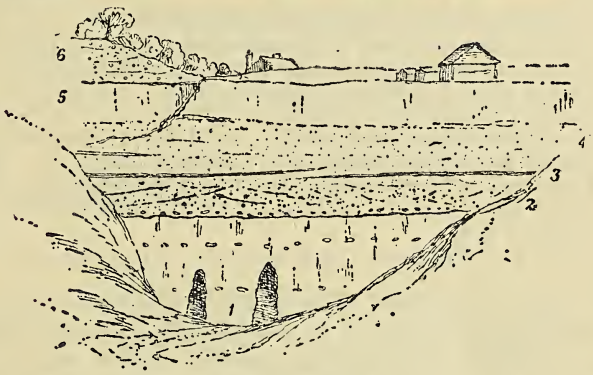
In Thorpe Hamlet—which forms the eastern part of the city—there are two pits which should be visited. At the St. James' pit an excellent section of the Crag beds is shown:—

		Feet.
Upper Crag	False-bedded white, yellow, red, and grey sand and fine gravel, with an impersistent mass of laminated clay near the middle, at the eastern end of the pit - -	25
	Laminated clay and sand - - -	3
	Gravel and large worn flints, resting on an irregular surface of Chalk, with nests of ironsand and comminuted shells. *Mytilus edulis*, *Astarte borealis* - - -	2
Chalk.		

In the large pit south of Bishop's Bridge, called Lollard's Pit, Mr. Woodward sketched the section shown in Fig. 27:—

Fig. 27.

Pit near St. Matthew's Church, Thorpe Hamlet.



Glacial Drift	6. Sand and coarse gravel.
	5. Brickearth (stony loam).
Upper Crag	4. Pale grey and yellow sand and fine shingle.
	3. Streaks of laminated clay.
	2. False-bedded brown and yellow sand and shingle, with "stone-bed" at base.
	1. Chalk with flints.

The clay (3) Prof. Prestwich* classed doubtfully as Chillesford Clay. He also remarked that small patches of shells are occasionally found in the lower part of the Crag.

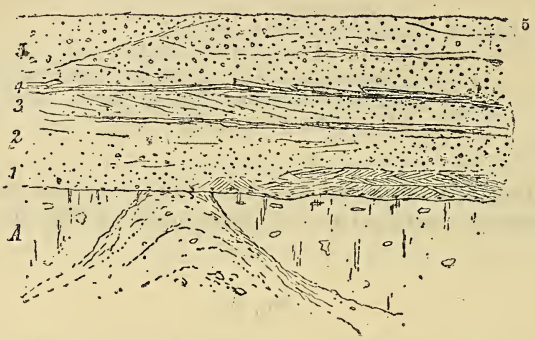
Thorpe, about a mile further east, is one of the best-known localities of the Norwich Crag. Three pits have been opened at the eastern extremity of the village; the one at the kiln immediately west of the Cromer branch railway (where it crosses the Norwich and Yarmouth road) is the only pit where shells are now obtained. The general section of the Crag at Thorpe Kiln will be

* *Quart. Journ. Geol. Soc.*, vol. xxvii. p. 469. (1871.)

seen from the accompanying section (Fig. 28) noted by Mr. Woodward in 1875.

Fig. 28.

Section at Thorpe Lime-kiln, near Norwich.



	Feet.
5. Irregular sandy capping, thickening out to - - -	4
4. False-bedded sand and shingle, formed chiefly of flint and quartz, hardened in places and at various levels into a black ironstone-conglomerate or "iron-pan," which contains casts of shells - - - -	8 to 12
3. False-bedded sand and pebbly gravel with irregular seams of micaceous sandy clay; shells at base -	2 to 4
2. White and buff false-bedded sand with shell-patches -	5 to 6
1. Rolled flints and clay, with sand, pebbles, and shells, "Stone Bed" - - - - - - -	1 to 2
A. Chalk with flints and "paramoudras," 20 feet shown.	

The strata are clearly shown, but not the sub-divisions that have been made. There is a conspicuous shell-bed, sometimes six feet in thickness, occupying patches in the white and buff-coloured sand (2) stretching along the face of the quarry, and there are thin beds of brown rudely stratified and impersistent clay above it (3)—termed by some the Chillesford Clay. Shells are found at all horizons between the Chalk and this clay, but they are very local, for in places the beds are entirely unfossiliferous from top to bottom. Nowhere are there two marked or persistent horizons of Crag beneath this clay.

The Stone Bed, about 2 feet in thickness, contains great boulders of flint in a loamy matrix, and yields *Pecten opercularis*, *P. pusio* (one specimen), *Tellina obliqua* (pairs), *Tellina crassa*, *Mytilus edulis* (pair), *Mya* (pair), *Mactra*, *Buccinum tenerum*, *Trophon antiquus* (large specimens), &c.

The bones occur most abundantly *on* the surface of the Stone Bed, not so often in it or under it. Mr. Woodward obtained a portion of a tusk in September 1878, and saw, the day after, the exact position in which another portion of tusk, 4 feet 6 inches in length, had been obtained. This was on the surface of the Stone Bed.

Casts of shells, "about 10 or 12 feet higher than the bed of rejectamenta," were noticed so long ago as 1837 by the Rev. Thomas Clowes. They occurred in the "iron-pan," and Mr. Woodward recently obtained the following species at the eastern end of the pit:—

Littorina littorea.
Purpura lapillus.
Cardium edule.
Modiola (large sp.).
Mya arenaria.
Mytilus edulis.
Nucula Cobboldiæ.
Tellina balthica?
——— obliqua.

If *Tellina balthica* is correctly determined this is the only instance of its occurrence near Norwich, the specimens previously recorded being of doubtful origin. A complete list of the species found in the lower beds at this locality will be found in Mr. Woodward's Memoir.

The various pits near Postwick are now much overgrown, but most of them appear to have been fossiliferous, and this is one of the best known localities for Norwich Crag shells. In the pit near Postwick Church the surface of the Chalk was drilled by Annelids and contained *Pholas crispata*. East of Postwick the Chalk sinks below the marsh-level, so that we can now no longer find any base to the Crag. At the same point that the beds sink, there appears to be a tendency for the laminated clays to thicken and become more persistent—as they always seem to do towards the east. A section in the wood south of Brundall Church well illustrates this change:—

		Feet.
	Warp - - - - -	3 to 5
Upper Crag	Pebbly sands - - - -	6
	Laminated clay - - - -	5
	Sands with an occasional gravelly seam, and shells at intervals. Base not seen -	15

In this pit univalves were scarce, even *Littorina littorea* was rare, but the Crag was especially rich in *Cyprina islandica*, entire valves of which, though not in pairs, were abundant. *Astarte borealis*, *A. compressa*, *Leda oblongoides*, *Lucina borealis*, and *Tellina obliqua* were common; while *Tellina prætenuis* and *Nucula Cobboldiæ*, the latter most abundant in the railway cutting further east, were rare.

The railway cutting just mentioned shows three feet of laminated clay, besides numerous seams of clay in the overlying pebbly gravel. About a quarter of a mile east of the Station the clay has been dug for brickmaking, having a thickness of seven or eight feet. East of this point the shelly strata seem to have entirely disappeared beneath the sea-level, and the description of the overlying laminated clays and pebbly gravels will be left for another Chapter.

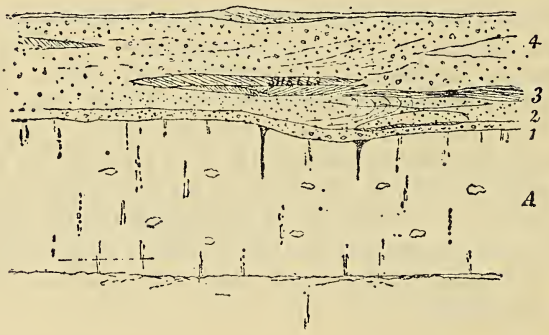
On the opposite (south) side of the river the deposits are similar, but the pits at Whitlingham, Bramerton, and Surlingham

may be described; for at Whitlingham was found the tooth of Mastodon, figured by William Smith;* Bramerton is commonly taken as the typical locality for the Norwich Crag, where the shell-beds can be divided into two zones; and Surlingham has also yielded a tooth of Mastodon.

Numerous pits which have been opened for the working of Chalk at Whitlingham have also exposed the Crag, and two were being worked in 1875–1878. In the larger pit the strata are variable and at one time displayed a remarkable disturbance, caused by glacial action. One face of this pit showed (in 1877) the following section, observed by Mr. Woodward:—

Fig. 29.

Section at Whitlingham.



	Feet.
4. Pebbly gravel and sand, with seam of shells - -	
3. Laminated clay and seam of shells - - -	15 to 25.
2. Sand and pebbly gravel with patches of shells -	
1. Stone-bed - - - - - -	
A. Chalk.	

This section exhibited one of the lenticular masses of laminated clay sometimes called "Chillesford Clay"; it overlaid a bed of shells, and was itself overlain by two similar beds, one of which it perhaps partly replaced. At this time (1877) the eastern face of the pit showed no distinctive clay-band at all, and while at one time it exhibited a small nest of shells, on a subsequent visit this was quite worked away. This pit alone shows that no distinctive horizons can be traced out in the Upper Crag by the occurrence either of shell-beds or of laminated clay. Diagrams drawn at different times, as the beds are worked away, are quite different in detail.

The pit on Bramerton Common, though now far inferior in its exhibition of the beds to either Whitlingham or Thorpe, has always been treated as a typical section of the Norwich Crag;

* Strata identified by Organized Fossils. 4to. 1816.

Mr. Woodward's description* is therefore here reproduced in full. The section is as follows :—

	Feet.
Very fine sand with gravelly seam at base - -	1 to 2
False-bedded ferruginous sand with pebbles of flint, quartz, &c. - - - - - -	2
Blue and brown mottled clay - - - -	1
Sand with shells. Zone of *Astarte borealis* - -	2
Seams of brown clay - - - - -	20 or 21
Sand with a few stones and shells sparingly (about 12 feet) - - - - - - -	
Seams of brown clay (6 ins.) - - - -	
Shell-bed with seams of brown clay (about 6 feet) -	
Bed of flints (1 foot) with *Mya* in natural position -	
To Chalk with flints (about 2 feet above the river-level)	about 27

"R. C. Taylor, who described the section in 1823, gave a thickness of 50 feet for the Crag, and mentioned three distinct beds with shells. Samuel Woodward gave the thickness as 60 feet, and his account varied very much from Taylor's. Indeed every section taken at intervals must vary as the beds themselves are so changeable. I am entirely unable to agree therefore with the special correlation made with the beds at Chillesford and elsewhere. In a large way the beds correspond, but it is impossible to correlate minute divisions which change as the beds are worked away.

"Bramerton has always been the chief collecting ground. Sowerby's specimens were nearly all obtained from this locality; so also were those enumerated by Mr. S. V. Wood in his Crag Mollusca. *Tellina balthica* therein recorded by him, has been subsequently regarded as an erroneous statement: it has never been met with by Mr. James Reeve during his exhaustive examination of the beds. To Mr. Reeve indeed we are mainly indebted for our present knowledge of the Bramerton Crag fauna.

"A large mass of Chalk was found at the foot of the Cliff at Bramerton by the Rev. W. Foulger, perforated by the *Pholas crispata*, 3 inches in diameter. Similar borings were also detected by the Rev. T. Clowes.

"*Hydrobia subumbilicata* have been found in some abundance in the lower bed on Bramerton Common by Mr. Reeve, but so far as I am aware all of the freshwater shells are very rare. Sections of the pit on Bramerton Common have been published by Mr. S. V. Wood, jun., in his Remarks in Explanation of Map (1865), Sec. 24; and in conjunction with Mr. F. W. Harmer, in the Supplement to the Crag Mollusca, Sec. XVI.

"Shells were noticed further east, so far as the boundary with Surlingham parish, by J. W. Robberds; and by S. Woodward 'about 300 yards lower down the river by the side of a cottage. This would be about the spot where we now find the excavation

* Geology of the Country around Norwich (*Memoirs of the Geological Survey*), pp. 82, 83.

known as 'Blake's Pit,' to which Mr. J. Reeve directed attention in 1870. The Crag here is often called the 'Scrobicularia bed' from the abundance in it of *Scrobicularia plana*. Mr. S. V. Wood says it 'appears to intervene between the few feet of specially Fluvio-marine Crag which rests on the chalk and the Chillesford bed.' For my own part I cannot recognize such a distinction. Blake's pit shows a mass of shells and sand from top to bottom, with included streaks of clay. The *Scrobicularia* so abundant here is very rare in the adjoining exposures on the Common. Many of the shells are highly stained with iron-oxide in Blake's pit, and present quite the appearance of Red Crag fossils." East of Bramerton the Chalk disappears beneath the marsh level, but shelly Crag can be traced for about one and a half miles further.

In 1873 Mr. Gunn drew attention to the discovery of a Mastodon's tooth in the beds in a pit near Surlingham Wood. The following was the section then recorded :—

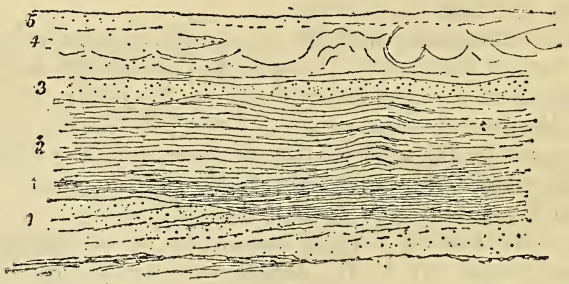
	Feet.
7. Gravel, from which a Neolithic implement was taken.	
6. "First-rate Chillesford Clay" - - - -	10
5. Bright yellow sand in which the tooth was found - -	3
4. Red gravel.	
3. Lighter coloured clay with large interspaces of sand, beautifully laminated - - - - -	8
2. "Chillesford Clay" more compact, and the lower part of a darker bright blue colour - - - -	10
1. Fine sand in which shells were found 6 feet below the clay.	

Associated with the tooth were broken fragments of a leg bone of the Mastodon or Elephant. The tooth bore a matrix of dark-coloured gravel and sand, thus differing from the sand in which it was found. Mr. Gunn considered that it was derived from the Stone Bed.

The following was the section of the pit when Mr. Woodward visited it in 1877.

Fig. 30.

Section at Surlingham Wood.



		Feet.
Upper Crag	5. Warp - - - - -	2 to 3
	4. Brown clay, sand, and gravel, contorted	5
	3. Sand in which bones had been found -	1 to 2
	2. Laminated clay and sand - -	10 to 12
	1. White false-bedded sand.	

Here again there seems to be a great tendency for the clay beds to thicken towards the east as they sink beneath the sea-level.

This completes the description of the typical Norwich area, and it only now remains to speak of the transition district of the Bure Valley, where the overlap spoken of in former Chapters seems often to lead to the gradual disappearance of the lower part of the Norwich Crag, and to the consequent superposition of the newer Weybourn Crag immediately upon the Chalk.

North of Norwich the shelly Crag first reappears in the valley, tributary to that of the Bure, at Spixworth, Crostwick, and Rackheath. These sections are poor, and principally interesting as yielding *Tellina balthica*. At the lime-kiln north of Rackheath Church, the Crag would at first sight be termed unfossiliferous, but casts of shells are here and there preserved in thin bands of ironstone; the following is the section:—

		Feet.
Upper Crag	Pebbly gravel	6
	Black ironstone and indurated sand with ironstone nodules, and casts of *Cardium edule* and *Littorina littorea*	½
	Yellow sand and gravel	9
	Laminated sandy clay, disturbed at top	1 to 1½
	Fine buff sand with gravelly seams	1½
		18½

Chalk.

About three furlongs further north the same beds show shells in abundance: here the section is as follows:—

		Feet.
Upper Crag	3. Pebbly gravel with shells up to the surface	6
	2. Laminated clay	½
	1. Shell bed, sand and gravel	2

Chalk with flints.

This is one of the most instructive sections in the Bure Valley: it exhibits the (occasionally) fossiliferous nature of the "Pebbly sands and Pebble beds" ("Bure Valley Beds"), and shows that in point of structure they cannot be separated from the Norwich Crag.

The following species of shells were collected from this exposure of the Crag, by Messrs. S. C. Sothern and H. B. Woodward.

	Bed 3.	Bed 1.
Littorina littorea	×	×
Natica catena ?		×
Scalaria grœnlandica	×	
Astarte borealis	×	(very abundant).
——— compressa	×	×
Cardium edule	×	×
Cyprina islandica	(fragments)	×
Mya arenaria	×	
Mytilus edulis		×
Nucula Cobboldiæ	×	×
Tellina obliqua	×	×
——— prætenuis	×	×
——— balthica	×	

In the talus was found a fish-bone, fragments of *Mactra*, *Trophon antiquus*, and *Purpura lapillus*.

Continuing northward a pit near Wroxham Park, situated to the east of the Hall near the farm-buildings, showed the following section :—

		Feet.
Upper Crag	4. Sand and pebbly gravel 3. Shell-bed (impersistent), sand and gravel	8 to 10
	2. Laminated clay and sand	1
	1. Sand and shell-bed	1½
Chalk with flints.		

In bed No. 3 *Tellina balthica* is found abundantly, and it is also said to occur in No. 1. Prof. Prestwich considers that the clay, No. 2, represents probably the Chillesford Clay, but it seems unsafe to hazard the identification of so thin a seam.

East of Wroxham the surface of the Chalk sinks beneath the marsh level, and as it sinks the lower part of the Crag also disappears, and there is an indication of the tendency of the clay beds to thicken towards the east—as we find in so many other places.

The brickyard east of Wroxham Station displays a thick mass of laminated clay and sand, which is used for the manufacture of red bricks. The section at the northern end of the pit showed the following beds :—

		Feet.
	Warp	4 to 5
Upper Crag	False-bedded sand with seams of gravel, and irregular seams and streaks of laminated clay, fragments of carbonaceous matter, ironstone nodules	8 to 9
	Very micaceous, greenish-grey, laminated clay and sand, having a wavy appearance; in one place let down probably by dissolution of Chalk beneath	18
	Red sand and gravel.	

At the southern end of the pit the beds were overlain by 3 or 4 feet of brown Clay and Gravel, representing probably the Contorted Drift. Mr. Woodward was unable to trace the laminated clay further east, and it tapers away westwards through Belaugh parish. This section will be again referred to in the next Chapter.

In the lower part of the valley of the Bure the upper portion of the Crag Series is exposed over a wide area; but as the pebbly gravels are unfossiliferous, and probably newer than the mass of clay at Wroxham, they need not be described here. We will now mention the more important exposures in the higher part of the valley, between Wroxham and Aylsham.

The first of these is at Belaugh, where shells are met with in an excavation by the side of the hill, near the Farm buildings, about a quarter of a mile north-west of the church. The following is the section, the lower part of which was opened up in 1877 :—

		Feet
Upper Crag	Pebbly sand	10 or 12
	Brown pebbly sand with shells	3 to 4
	Sand	4½ to 5
	Laminated clay and sand	½
	Stiff brown and blue clay	1
	Sands and clays	3½
	Large flints (? stone bed).	

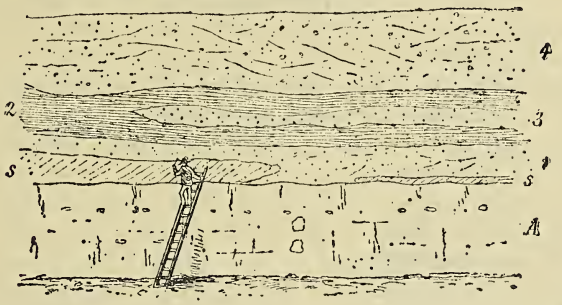
The Chalk itself in this neighbourhood has been eroded so as hardly to present any actual exposure in the low line of hills bordering the river. This pit has yielded a considerable number of species of mollusca, all of which, except the thin-shelled *Thracia papyracea* occur also in the Weybourn Crag of the coast.

One of the best sections of the Crag in the Bure Valley is that seen a little to the south-east of Coltishall Railway Station.

Fig. 31.

Section at Coltishall.

(H. B. Woodward.)



	Feet.
4. False-bedded pebble gravel and sand - - -	9 to 12
2. Laminated clay with bed of sand (3) - - -	6 to 6½
1. False-bedded sand, gravel, and shell-beds (*s*) with seams of clay and clay-pebbles - - -	5
A. Chalk, with flints and paramoudras, about 12 feet exposed.	

A bed made up of specimens of *Mytilus edulis* occurs from 1 to 2 feet above the Chalk; a similar bed occurs at Wroxham. At one time the shell-bed abruptly terminated in a mass of buff unfossiliferous sand. One conspicuous feature was a tongue of sand, which divided up the laminated clay in the part of the pit worked, and whose lower junction with the clay would, if isolated, have been taken for an unconformity between the "Chillesford Clay" and overlying sand. The gravel above also rested in one place on an eroded surface of the clay beneath; an erosion which may have been caused by springs in recent times. The clay itself becomes more and more interbedded with sand, until in one place it passes into a merely subordinate feature. In this pit *Tellina balthica* is not found, but another section near the Anchor Inn yields that shell in abundance, though the relation of the shelly Crag to the clay cannot there be made out.

On the opposite side of the river, in the parish of Horstead, the Crag has been largely opened up, on account of the numerous excavations for Chalk. The last working was closed in 1877, the ground being sloped and planted with fir trees, but the discovery of a skeleton of Mastodon in 1820 must always render the locality of interest. Mr. H. B. Woodward has given a full account of the discovery,* and inclines to the opinion that a

* Geology of the Country around Norwich (*Memoirs of the Geological Survey*), pp. 57, 58.

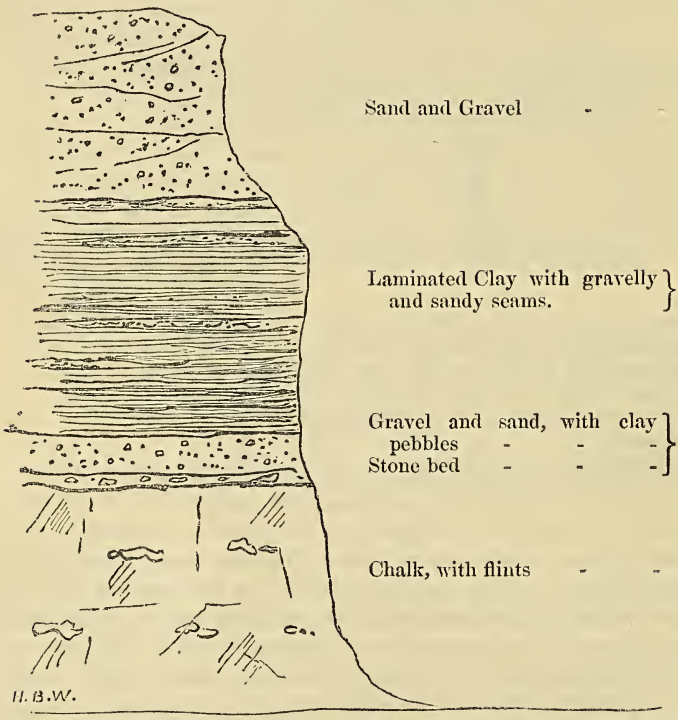
large portion of the skeleton, at any rate, was found. It seems however, rather singular that only one tooth should have been preserved. This is the most northerly point to which the Mastodon has been traced, for it is entirely absent from the Cromer Forest-bed.

At Burgh-next-Aylsham we meet with the last section of the Norwich Crag, as distinct from the newer Weybourn Crag, and here also the so-called Chillesford Clay occurs in considerable thickness.

Fig. 32.

Section at Burgh Kiln, near Aylsham.

(H. B. Woodward.)


Sand and Gravel - - 6 feet.
Laminated Clay with gravelly and sandy seams. } 6 or 7 feet.
Gravel and sand, with clay pebbles - - - }
Stone bed - - - } 1ft. to 18in.
Chalk, with flints - - 6 to 8 feet.
H.B.W.

The following list includes all the species recorded from this locality:—

Littorina littorea.
Scalaria grœnlandica.
Trophon antiquus, var. striata.
,, ,, var. contraria.
Turritella terebra.
Astarte borealis.
,, compressa.
Cardium edule.
Cyprina islandica.
Corbula gibba.
Cyclas cornea.
Corbicula fluminalis.
Leda oblongoides.
Lucina borealis.
Mactra ovalis.
Mya arenaria.
Tellina lata.
,, obliqua.

There is nothing in the list to distinguish the deposit from the Weybourn Crag, except the absence of *Tellina balthica*; but this, and the occurrence of the thick mass of clay, seem to support the contention of S. V. Wood, junr., that the deposit belongs to the older series.

CHAPTER VIII.

CHILLESFORD CLAY AND WEYBOURN CRAG.

In the last Chapter the Pliocene strata were followed northward, until Red Crag gave place to Norwich Crag, and that in turn was overlapped by Weybourn Crag. We will now return to the southern portion of the district and notice the sections of the overlying Chillesford Clay—many of them already incidentally alluded to in previous Chapters. The Chillesford Clay is here treated of apart from the underlying beds, because it points to the commencement of somewhat different conditions. The deposition of shelly Crag gave place to that of strata consisting largely of laminated micaceous clay, sometimes with lignite and sometimes with bones of stranded cetaceans, but seldom containing mollusca. These laminated clays seem to indicate more estuarine conditions and shoaler water, for it is under such circumstances that thin alternations of sand and clay are laid down, and the skeletons of whales also point to muddy shoals, among which the animals became entangled and stranded.

The Weybourn Crag is treated of in the present Chapter, for recent observations seem to indicate that this deposit may be merely a sandy modification of the Chillesford Clay, coming on as the strata are traced beyond the limits of the sheltered estuary to an area where marine mollusca could flourish. It must have been laid down in shallow water, for though lying at a lower level than the Crag at Norwich it indicates quite as littoral conditions.

The southernmost outlier is found at Walton Naze, where the carbonaceous clay overlying the Red Crag has been identified with the Chillesford Clay by Prof. Prestwich and by S. V. Wood, jun. Mr. Whitaker, whose section has already been quoted in Chapter VI. (p. 83), follows their determination, though with some doubt; but after a re-examination of the cliff I cannot help feeling uncertain whether the clays and gravels do not represent rather the Cromer Forest-bed. A section about 12 chains south of Walton Tower showed in 1886:—

		Feet.
	9. Soil	1½
Chillesford Clay? (or Forest-bed).	8. Gravel of unworn flint, with abundance of flint, quartz, and quartzite pebbles—no Boulder Clay stones observed	5
	7. Bedded loam, with scattered angular flints and pebbles	1 to 3
	6. Gravelly sand	⅓
	5. Stiffer loam (base blue clay)	1½
	4. Black carbonaceous loam with decayed wood and obscure vegetable impressions	1
	3. Gravel of unworn and worn flints, quartz, and quartzite (as No. 8)	½
	2. Red sand (decalcified Crag)	6
	1. London Clay.	

All the strata above the red sand seem to belong distinctly to the same series, and gravel of similar composition occurs throughout. The absence of Boulder Clay stones, and the abundance of the peculiar quartzites so common in the Forest-bed, make the gravels very like those of the Forest-bed series at Bacton and Weybourn. These pale-coloured close-grained quartzites are found throughout the Newer Pliocene beds, but are particularly abundant in the estuarine gravels of the Forest-bed. In the Glacial Deposits they are replaced by liver-coloured or red quartzites of a different character. The clays are apparently of fresh-water or flood origin, but I could not obtain a sample sufficiently well preserved for microscopic examination. The wood also was much decayed. Within a short distance of the section just noted the clay overlaps upon the Eocene beds.

The first undoubted exposures of Chillesford Clay occur about 18 miles north-north-east of Walton, in the district around Chillesford and Butley, where the clay forms a wide sheet, resting on the Chillesford Crag or on the upper Red Crag. At Chillesford the deposit consists of a fine-grained micaceous loam, too pervious to preserve fossils well, and often thoroughly decalcified. It has only yielded cetacean bones and a few casts of Mollusca. For some reason that I am unable to explain fossils decay more readily in a sandy loam than in a sand. Thus beds of loam in the Crag often only contain obscure casts, though the associated sands above and below may yield well-preserved shells. Bones (phosphate of lime) do not disappear so readily as shells (carbonate of lime).

The clay is well exposed in the pit at Chillesford brickyard, where it reaches a thickness of about 17 feet, the upper part being cut off by Boulder Clay. The base and the gradual passage downward into the underlying Chillesford Crag can, however, be more readily examined in the pit near the Church, where Prof. Prestwich describes the deposit as "grey clay with a few shells and fish-vertebræ, passing down into light-coloured clayey sand, with patches of perfect but friable shells."* In the brickyard only impressions of shells occur, though cetacean bones are not uncommon, and the skeleton of a whale 31 feet long was found some years since.† It is unfortunate that the specimen was left exposed to the weather and has now entirely decayed. I was unable to find any trace of the shells in 1886, but Prof. Prestwich records *Arca* [?], *Cardium grœnlandicum*, *Cyprina islandica*, *Leda myalis*, *Nucula tenuis*, *Tellina lata*.

As this is the typical section of the Chillesford Clay, a sample was washed and examined, to trace if possible the origin of the material. Microscopically it consist of fine clay with a small quantity of silt-sand, plates of mica often $\frac{1}{20}$ inch in diameter, and a good deal of limonite. Not a single large grain of sand, and no microscopic fossils were seen in the sample examined. The sand consists almost entirely of quartz, in small little-worn grains half of which are milky and half clear. One or two

* *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 336. (1871.)
† *Rep. Brit. Assoc.*, 1868, Trans. Sect., p. 61.

microscopic splinters of flint were observed, and a few dark-green opaque rounded or nodular grains, probably glauconitic.

From Chillesford the clay stretches northward in an almost continuous sheet as far as the Alde, but it is unnecessary here to follow the outcrop, which has already been minutely described by Prof. Prestwich* and the Rev. O. Fisher.† The section at Iken Brickfield is, however, of special interest, for the pit—which lies nearly a mile and three-quarters east-south-east of Iken Church—shows a distinct overlap of the Chillesford Clay, so that it rests directly on the Coralline Crag. The section published by Prof. Prestwich in 1849 was :—

	Feet.
Flint gravel	1 to 3
Laminated grey clays and sands with indistinct impressions of shells	10
Yellow sands	4
Coralline Crag	+30

In 1886 the actual junction of the beds was no longer visible, but there is certainly not room for more than about two feet of strata between the Clay and the Coralline Crag, which is still visible in the middle of the pit. The base of the clay contains large unworn and unbroken flints. Bones have also been found, though not lately—unfortunately none of them appear to have been preserved.

Crossing the Alde the Clay reappears around Aldborough, and on Aldringham Common, but the pits are of little interest, and the deposit seems to a large extent to be cut out by later gravels. North of Southwold, however, the Clay comes on in considerable thickness and can be traced continuously at the foot of the cliff, wherever sections are visible. We will therefore now follow the coast-line northward, only referring to inland sections where they are necessary to fill up breaks in the continuity of the cliffs. Of the cliffs we have carefully measured sections, made during the course of the Survey, by Messrs. Whitaker (Easton to Covehithe)‡ and Blake (Kessingland and Pakefield).§

In the Easton Bavent cliffs the Chillesford Clay commences as a thin deposit only 5 or 6 feet thick, but rapidly increases in importance towards the north, till it reaches nearly 20 feet. It consists of laminated loam and clay, often very sandy, and only yielding fossils at the northern end. Here Prof. Prestwich found the following species :—

Buccinum undatum.	Leda myalis.
Littorina littorea.	Lucina borealis.
Natica cirriformis.	Mactra ovalis.
Purpura lapillus.	——— subtruncata.
Turritella communis.	Mytilus edulis.
	Nucula Cobboldiæ.
Astarte compressa.	Tellina lata.
Cardium edule.	——— obliqua.
Corbula.	
Cyprina islandica.	One leaf-impression.

* *Quart. Journ. Geol. Soc.*, vol. v., p. 345 (1849) ; and vol. xxvii., p. 338.

† *Ibid.*, vol. xxii., p. 19. (1866.)

‡ Geology of Southwold and of the Suffolk coast from Dunwich to Covehithe; plate. (1887.)

§ Horizontal Sections, Sheet 128.

There is nothing in the list to fix the age of the deposit, though *Tellina balthica* is missing. At this spot the underlying Crag disappears beneath the sea-level for some miles, and we can no longer ascertain the total thickness of the Chillesford Clay, except by boring.

The coast-line is now occupied by Alluvium and by Easton Broad for about a mile, but this gap is largely bridged over by outcrops along the borders of Easton valley. Good sections are visible at the Frostenden and South Cove brickyards, though in neither pit is the base of the Clay reached.

In Covehithe Cliff the Chillesford Clay has been exposed continuously for about a mile. It is described by Mr. Whitaker as "loams with occasional sands," and in one place he notes* some curious contortions which seem to be cut off by bedded sands also belonging to the Chillesford Series.

There is now another gap of about two and a half miles, only partially bridged over by inland outcrops. At the northern end of Covehithe Cliff the Clay can be followed continuously round the edge of the small valley to within half a mile of Benacre Church. Another doubtful patch has been mapped north of Benacre, and loamy clay has been dug to a depth of 10 feet north-east of Henstead Hall Farm. On the north side of the valley Mr. Blake has found a small outcrop on the border of the marsh south-west of Kessingland Church.

We now enter the district in which the fresh-water and estuarine beds known as the Cromer Forest-bed undoubtedly appear; but before continuing the description of the Chillesford Clay in the Kessingland and Pakefield cliffs, it will be advisable to allude to the divergence of opinion which exists as to the relation of these deposits to each other. Mr. Blake considers that the Chillesford Clay alternates with the Forest-bed series, and he identifies with the Norwich Crag some gravel with mammalian remains, underlying laminated clays.† After a careful examination of the coast, and after putting down borings in various places, I am unable to accept this view, for the Forest-bed seems always to rest on an irregular channelled surface of Chillesford Clay or Crag, as it does near Cromer. Part of the clay identified by Mr. Blake with the Chillesford Clay appears to be fluviatile or estuarine clay of the Forest-bed, and the underlying mammaliferous gravel is merely the base of the deposit. The mammalia are characteristic Forest-bed species, not Norwich Crag forms. This subject will be returned to in the next Chapter.

At the point where the cliff recommences, at Beach End, Kessingland, the Chillesford beds reappear with the same character as at Covehithe, consisting of laminated micaceous grey clay and buff sand, resting on orange loamy sands with a few stones. The sands were so full of water that the borings could not be carried below the level of mean tide, but I think

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* Geology of Southwold, &c., plate, section C.

† Horizontal Section, Sheet 128 (Geological Survey); and Explanation, 8vo.; Presidential Address, *Proc. Norwich Geol. Soc.*, vol. i., pp. 137–160.

there is no doubt that these strata belong, as Mr. Blake considers, to the Chillesford series. The section a few yards north of the flagstaff was :—

	Feet.
Greenish-grey unstratified clay (Rootlet-bed) - -	4
(Strata hidden by Blown Sand) - - - -	3
Buff, orange, and white micaceous sand, the lower part full of water - - - - - - (bored)	12½

Here all the beds beneath the Rootlet-bed may represent the Chillesford Clay, at this point exceptionally sandy. Or the underlying Crag may also be shown, though no shells were met with.

From the old Coastguard Station, as far northward as the parish boundary, there seems to be an ancient channel, occupied by the carbonaceous and gravelly beds of the Forest-bed series, which none of the borings appear to have pierced. At sixty yards north of the boundary, in Pakefield parish, red shelly Crag was met with at about the level of low water. Then there is another channel, north of which the Chillesford Clay rises rapidly, so that at sixty yards south of the Lighthouse Gap we find fine sand without stones, and thin clays, extending to the level of low-water. One hundred yards north of the Gap a deeper boring, commenced at about high-water mark, showed:—

	Feet.
Laminated light-blue and ferruginous micaceous clay and sand - - - - - - - - -	13½
Brown loamy sand, with thin seams of light-blue clay -	3
Sand, full of water - - - - - -	1½
	18

The whole of these clays and sands probably represent the Chillesford Clay, unless the lowest foot and a half belongs to the Crag. There may be a perfect passage from one to the other. From this point the strata can be traced without material change for half a mile, till they are permanently hidden by the sea-defences and sand-dunes opposite Pakefield.

When Pliocene strata reappear in the cliff at Corton, north of Lowestoft, the lowest deposit visible seems to belong to the Forest-bed, and the beds are so gravelly and full of water that none of the trial-borings could be carried below the level of low-water. Then there is another long stretch of coast of over 20 miles, throughout which Pliocene deposits never rise above the sea-level.

This break in the visible continuity of the Chillesford Clay is unfortunate, for it makes it impossible to feel certain as to the age of the similar strata which underlie the Forest-bed where it reappears near Happisburgh. The inland sections to a certain extent help to bridge over the gap, but the intervals still left are too wide to be ignored, especially in deposits of so variable a character.

Turning westward, up the valley of the Waveney, we find undoubted sections of Chillesford Clay at Aldeby, and what is probably a sandy modification of the same deposit on the opposite side of the river, close to Beccles. The Aldeby sections have already been described (pp. 108, 109). Those on the south side of the valley are interesting inasmuch as they show an alternation of laminated loams, sands, and seams of pebbles, as though the Chillesford Clay passes not only downward into the Crag, but upward by alternation into the Pebble Gravel—as is perhaps the case in other areas also.

The most characteristic of the sections near Beccles—and the only one that really justifies the mapping of the deposit as Chillesford Clay—is at Ingate Clay Pit, half a mile east of the town, where we find the following section :—

	Feet.
Soil (sandy) - - - - - - - -	2
Pebbly sand - - - - - - - -	3
Loamy Chillesford Clay, upper part brown, lower blue and stiffer ; a good many thin ferruginous seams occur, which have to be separated before it is used for bricks ; there is also too much sand, which also lowers its value - -	14
Hard pan and sand.	

For half a mile further east the outcrop of this clay has been traced on the Map ; but to the west of Beccles the deposits are much more sandy, and though probably of the same age, cannot be mapped as clays.

About seven miles north of Aldeby micaceous clays of the ordinary character reappear at Reedham and Limpenhoe, and Mr. Blake has been able to follow the outcrop for some distance at each place. One of the sections at Reedham, three-eighths of a mile east of the station, is described as showing a thickness of 11 feet of these laminated clays and sands, the pebble gravel resting on a distinctly eroded surface of the clay.*

Four miles west-north-west of Limpenhoe we find the sections at Surlingham, already described (p. 126). These lead us to the Norwich district, over which the clay is too thin and impersistent to be separated from the underlying shelly Crag.

In the Bure Valley the deposit reappears at Wroxham (p. 128), where it reaches a thickness of 18 feet, and at South Walsham. Masses of similar clay are seen at several other points, but these are the only ones that can be mapped. At both Wroxham and South Walsham the clay appears to be thickening, and at the same time sinking beneath the marsh level. Thus it happens that between the Bure Valley and the coast—a distance of nine miles—only exposures of the overlying Pebbly Gravels are visible ; though shelly Crag, of the age of the Weybourn Crag or perhaps newer, was met with in the railway-cutting south-east of Black

* Geology of the Country around Norwich (*Memoirs of the Geological Survey*), pp. 78, 79.

Mill, near Honing. The shells collected at Honing by Mr. H. B. Woodward were :—

Littorina littorea.	Mya arenaria.
Turritella sp.	Nucula Cobboldiæ.
Astarte borealis.	Tellina balthica.
Cardium edule.	——— sp.
Corbula gibba.	Balanus sp.
Cyprina islandica.	Foraminifera.

On the Norfolk coast, attempts were made to reach the beds underlying the Glacial Deposits near Eccles, but without success. About seventy yards south of the old tower of Eccles Church, a trial-boring made on the foreshore at half-tide level reached a depth of 12 feet, without penetrating the Till, and was then stopped by the rising tide. Another boring exactly opposite Happisburgh Church was more successful, for commencing below high-water level it reached a depth of 22 feet. The section was :—

		Feet.
	Till.	
Forest-bed	Sandy clay and sand (seen at the foot of the cliff) - - - - - -	2½
	Sandy clay and sandy gravel - - -	4
Chillesford Clay or Weybourn Crag	Clay and sandy clay, without stones, very micaceous - - - - -	17½
	Micaceous blue sand - - - -	½

No fossils were observed, but numerous grains of glauconite (?) and small particles of carbonaceous matter occurred in the lowest beds.

The eighteen feet of micaceous clays here found beneath the Forest-bed are so exactly like the Chillesford Clay of other localities, and hold so similar a position, that it is difficult to avoid referring them to the same horizon. But if we do so we must also consider the Chillesford Clay to be the equivalent of the Weybourn Crag; for as we shall show, there is little doubt of the continuity of the clays of Happisburgh with the shelly Crag to the north-west, the beds becoming more sandy and fossiliferous when traced in that direction.

At Mundesley the same clays were reached, for a boring on the foreshore about 200 yards south-east of the stream showed :—

		Feet.
Forest-bed.	Gravel pan.	
Chillesford Clay or Weybourn Crag.	Stiff or sandy dark blue micaceous clays, without fossils or lignite - - -	22

This trial-boring was commenced at half-tide level, the hard ferruginous gravel of the base of the Forest-bed being used as a convenient firm platform to work on. Immediately below this the character of the deposits suddenly changed, from coarse gravelly sands and carbonaceous clays, to fine-grained micaceous beds entirely without stones. The rods unfortunately parted at 22 feet, owing to the constant closing up of the hole through the softness of the clays, but the last sample brought up showed a single small fragment of shell, perhaps indicating the commencement of the shelly beds met with at Trimingham.

At Trimingham, on the shore due north of the village, one of the most important sections showing the relation of the Chillesford Clay to the Weybourn Crag was seen. The Weybourn Crag would here normally be almost entirely below the level of low-water, but some years since the weight of a large landslip from the cliffs forced the beds into an arch, and enabled me for a short time to examine the lower part of the section. Owing to the disturbance there is a little doubt as to the exact thickness of the lower beds :—

		Feet.
Forest-bed.	Carbonaceous clays with lignite, &c.	
Weybourn Crag	Laminated green and blue micaceous and rather carbonaceous clay	4
	Green loamy sand full of marine shells and containing teeth of *Arvicola intermedius*	3
	Laminated greenish clay as above	4

Here there is a mass of laminated micaceous clay, in the middle of which is found a shelly sand full of the common Weybourn Crag shells. The species found were :—

Buccinum undatum.
Littorina littorea.
Natica catena.
Pleurotoma turricula.
Purpura lapillus.
Trophon antiquus, reversed var.
Turritella terebra.
Astarte borealis.
——— compressa.
——— sulcata.
Cardium edule.
Corbula contracta ?
——— gibba.
Cyprina islandica.
Leda oblongoides.
Lucina borealis.
Mactra ovalis.
Mya arenaria.
—— truncata.
Mytilus edulis.
Nucula Cobboldiæ.
Pholas crispata.
Saxicava arctica.
Tellina balthica.
——— lata.
——— obliqua.

The Crag is exceptionally fossiliferous, but owing to its inconvenient position can seldom be examined. During the last ten years I have only once (in October 1889) been again able to examine it, though the stronger shells are still washed up after storms. *Tellina balthica* (Fig. 33) is perhaps the most abundant fossil.

Fig. 33.

Tellina balthica, Linn.

Natural size.

The Trimingham section just described is only three miles from the boring at Mundesley, but, owing to the accumulation of beach, I have not yet been able to examine the strata beneath the Forest-bed in the intervening area. It is here, if anywhere, that the relation of the Weybourn Crag to the Chillesford Clay must be made out, for the deposit at Trimingham is undoubtedly Weybourn Crag, and that at Mundesley seems decidedly to be Chillesford Clay. According to Prof. Prestwich, who correlates the Weybourn Crag with the Norwich Crag, we ought to find the Weybourn Crag to pass beneath the Chillesford Clay; according to S. V. Wood, jun., we ought to find it above that Clay, and alternating with the Glacial deposits. The most probable view

seems to be that the two deposits are synchronous, and that the Chillesford Clay passes laterally into the Weybourn Crag, or at any rate that the Weybourn Crag is equivalent to the upper part of the Chillesford Clay.

Between Trimingham and Cromer, when the foreshore below half-tide is laid bare, there may often be seen greenish laminated clay and clay ironstone, with thin seams of sand and lines of marine shells, principally in the state of ironstone-casts. The clay is often carbonaceous, and contains a little lignite; mammalian bones also occur now and then. The base of the deposit has not been reached, for the Chalk seen at Trimingham is brought above the sea-level by a glacial disturbance, and no trace of the Crag is seen resting on it. It is probable, however, that in this area the Chalk does not lie many feet below the sea-level.

The furthest point to the east to which the undisturbed Chalk has been traced is about half a mile east of Cromer Jetty, where at extremely low tides it is occasionally visible. Owing to the accumulation of beach the immediately overlying beds have not yet been examined, but higher up on the foreshore there are laminated clays and ironstone with casts of the ordinary Weybourn Crag shells. These rise to the level of mean tide—giving a total thickness of about 10 feet to the Crag.

The Weybourn Crag has been traced continuously from Cromer to Weybourn, except for short distances, where it is cut out by channels of the estuarine Forest-bed, or has been ploughed out by glacial action, so that Boulder Clay rests immediately upon the Chalk. All the sections are so fully described in the Memoir relating to this neighbourhood,* that it will only be necessary here to allude to those of especial interest, and to trace the general change in the character of the deposit as the Crag rises towards the west.

Between Cromer and West Runton there is a decided tendency for the Crag to become more sandy, and also more full of shells. In this distance, about two and a half miles, the Chalk rises from extreme low-water to about five feet above that level. The immediately overlying "stone-bed," or bed of large little worn flints that is always found beneath the marine Crag and upon the Chalk, is so firm and cemented with iron that not only does it show as a continuous ledge on the foreshore, but it protects the underlying Chalk, so that the junction can nearly always be examined. The smoothness and evenness of the denuded surface of the Chalk is very marked; for not only is there no piping, but even the slight hollows usually found are missing. This is probably owing to the absence of all percolation, and to the unusual softness of the Chalk, which in this district never forms submarine ledges at the present day.

Between the unworn flints of the stone-bed occur numerous specimens of *Mya arenaria*, *Tellina obliqua*, and occasionally of *T. balthica*, in the position of life—proving that we are dealing

* Geology of the Country around Cromer (*Memoirs of the Geological Survey*), pp. 11–19. (1882.)

with a true marine deposit, and not with flints left by the subterranean dissolution of the surface of the Chalk through the agency of percolating water. The mode of origin of a stone-bed can be well studied in the shallow sea off Cromer, where such a deposit forms the fishing ground on which crabs and lobsters occur so abundantly. The soft Chalk is readily bored by *Pholas*, *Saxicava*, and various annelids, which cause it gradually to crumble away and to leave behind nothing but the flints, mixed with a certain proportion of stones from the beach. This process is not confined to the area between tide marks, but will go on at any depth at which the Chalk may happen to be exposed, and in places where there are no currents sufficient either to move the flints or to erode the Chalk.

Immediately succeeding the stone-bed on this part of the coast is found a mass of falsebedded gravelly sand, either grey or red, with seams of clay. This deposit is full of shells, which are particularly well-preserved in the unweathered bluish sands, but often much decayed in the oxydized portion. It was from a mass of iron-grey Crag, found on the shore a quarter of a mile south-east of East Runton Gap, that the largest number of Weybourn Crag shells were obtained during the Survey; in fact this locality has yielded every known species belonging to the horizon (except the delicate *Thracia papyracea*), and a good many unknown elsewhere. The large number of species obtained was, however, largely due to the loose sandy nature of the deposit, which elsewhere is usually too much mixed with clay, or cemented with iron, to allow a sieve to be used. The fauna is a littoral one, and the shells are a good deal rolled. Mixed with them, as in the Norwich Crag, is found a considerable number of land and fresh-water species, together with a few bones of land-mammals.

The higher portion of the Weybourn Crag seems here generally to be cut out by the gravelly Forest-bed; but where preserved it consists of alternations of clay and sand, with seams of mussels, and abundance of single valves of cockle, *Tellina*, and *Donax*. The commonest shells are the littoral sand-loving forms, those inhabiting muddy shores, such as *Scrobicularia* and *Hydrobia*, being scarce. The total thickness of the Crag on this part of the coast nowhere reaches fifteen feet.

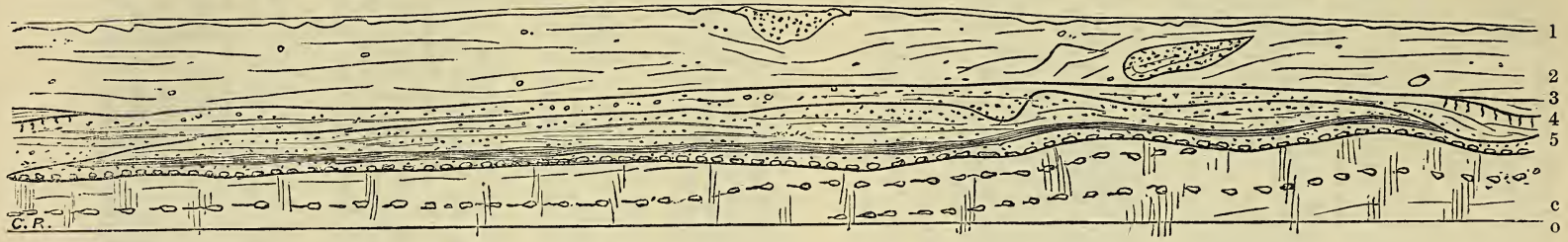
From West Runton to Sherringham the strata retain the same character, and the Chalk gradually rises to the level of high-water. There seem never to be more than a few feet of Crag beneath the Forest-bed, and in some places the Forest-bed rests immediately upon the Chalk. The principal interest of this part of the section is the occasional occurrence of *Pholas*-borings in the Chalk beneath the stone-bed.

West of Sherringham the Chalk continues to rise, till it forms a low cliff 20 feet high at Weybourn. As it rises the surface becomes more irregular and piped, so that the overlying deposits are often a good deal disturbed, especially close to Weybourn. A section near Weybourn (Fig. 34) will explain better than any words the relation of the different strata to each other.

Fig. 34.

Cliff section about 300 *yards east of the Coast Guard Station, Weybourn.*

E — Scale, 50 feet to an inch. — W



1. Loamy soil, often filling pipes in the marly Boulder Clay.

Contorted Drift - 2. Stony loam and marl, with included masses of sand.

Upper Freshwater Bed 3. Peaty loam, here unfossiliferous, but 100 yards further east containing opercula of *Bythinia* and *Cypris*.

Forest-bed?(estuarine) { 4. Sand, laminated loam, and quartzite-gravel; the upper part, where overlaid by the Freshwater Bed, is weathered into a loamy soil, and is full of small roots penetrating three or four feet. This has been termed the "Rootlet bed."

Weybourn Crag - { 5. Alternating loams and sands, with a bed of blue clay in the lower part and unworn flints at the base. Fossils at this place only occur near the Chalk; further east they are found throughout. (The thick bed of blue blay is identified by Prof. Prestwich with the Chillesford Clay, the shelly sands beneath being called Norwich Crag, and those above "Westleton Beds," see *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 460.)

c. Soft Chalk with layers of black or grey flints. Dip about S.S.E.

o. Ordnance datum (approximate).

I am unable to accept Prof. Prestwich's division of the Crag at Weybourn into three distinct series—Westleton Beds, Chillesford Clay, and Norwich Crag—for if the thick clay bed be followed a short distance, it will be found to pass into sand, and another seam will appear on a slightly different horizon, or the whole deposit will be split up into thin alternations of sand and clay. Wherever masses of shelly Crag were divided by laminated clays, collections were made from each and the results were compared, but all the shell beds seem clearly to belong to the same horizon. The "grey clay with fragments of wood," west of Sherringham, also identified with the Chillesford Clay by Prof. Prestwich, is on a different horizon; it belongs to the Forest-bed series, and has yielded a considerable number of mammalian bones.

At Weybourn the cliff comes to an end, and shingle beaches and salt marshes separate the higher grounds from the sea; but where the top of the Chalk is visible, Glacial Deposits rest immediately upon it, except at Letheringsett, near Holt. From the position and lithological character of the strata at this spot there is little doubt that they represent the beach deposit of the Weybourn Crag sea. No fossils were found, but the absence of shells is a common character in shingle beaches. The largest pit, marked *Kiln* on the map, is half a mile north-west of Letheringsett; it shows:—

		Feet.
Soil.		
Contorted Drift	Boulder Clay, very chalky	5
	Streaky brick-earth and marl	0 to 1
Weybourn Crag	Shingle, almost entirely flint	3
	Loamy sand and large worn flints	1
Chalk, probably 20 feet above the level of the stream.		

Another part of the same pit shows 3 or 4 feet of alternating laminated clay and lines of pebbles. A pit by Rook Hill, now disused and much obscured, shows similar though more sandy beds resting on the Chalk, which at that point is nearly 50 feet above high-water mark.

Mr. Woodward has recognised similar representatives of the Pliocene beds at Guist, in the Valley of the Wensum, about nine miles to the south-south-west of Letheringsett (Fig. 35, p. 143). This section helps to connect the strata with the Crag of the Norwich district; but whether the shingle belongs to the Weybourn Crag, or to an older division, there is nothing to show.

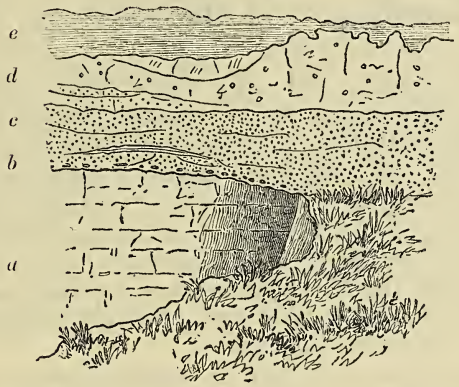
We have now traced, as far as possible, the stratigraphical relations of the Weybourn Crag to the Chillesford Clay, and to the Norwich Crag; but it still remains to see what assistance in the comparison of the different deposits can be obtained from the included mollusca. In the Bure Valley we find Weybourn Crag distinctly overlying the Norwich Crag, with sometimes a seam of clay, often identified with the Chillesford Clay, between. But in other cases the *Tellina balthica* Crag rests immediately on the

Chalk; or where the clay thickens it seems to have increased at the expense of the shelly Crag. The evidence is thus not perfectly

FIG. 35.

Section at the Lime-Kiln, Guist.

(H. B. Woodward.)



e. Brown stony, and sandy clay.
d. Chalky and sandy Boulder Clay, bedded at base, 5 to 6 feet.
c. Grey and buff micaceous sand and shingle, and laminated clay, with nodules of "race," 5 to 10 feet.
b. Stone-bed.
a. Chalk with flints.

satisfactory, for in this area the only grounds for the separation of the two horizons, is the supposed exclusive occurrence of *Tellina balthica* in the upper one. The list of mollusca from the upper bed in the Bure Valley is much too small to allow of any useful comparisons.

Failing vertical superposition, for the older deposit appears to be entirely absent in the continuous exposures of Crag between Cromer and Weybourn, we are compelled to fall back on the palæontological evidence, and to rely almost entirely on Lyell's test of the per-centage of recent mollusca contained in the beds. A much larger number of species, fortunately, has been obtained from the sections on the coast than from the Bure Valley, and though, perhaps, the number may still be too small to allow us to speak of the relative age of the deposits as being settled beyond further question, yet the direction in which the figures point is unmistakeable.

From the Weybourn Crag there have now been obtained 53 species and marked varieties of marine mollusca. Of these, five are extinct, showing a per-centage of 10·6, compared with 15·5 and 16·0 from the Chillesford and Fluvio-marine Crags respectively. But as the total number of species known from the Weybourn Crag is still considerably smaller than that from the older beds, and forms dying out are likely to be represented by

comparatively few individuals, the discrepancy is probably in reality somewhat less. The proportion of Arctic to Mediterranean forms is:—

——	Total.	Arctic.	Mediterranean.
Weybourn Crag - -	53	9	0
Chillesford Crag - -	90	7	2
Fluvio-marine Crag -	112	9	7

Two Arctic species and two characteristic Arctic varieties appear for the first time in the Weybourn Crag, viz., *Astarte crebricostata, Astarte elliptica, Astarte borealis*, oval var., and *Saxicava arctica*, gigantic var.—all four, however, being rare. Thus in the Weybourn Crag, in a list containing only half the number of species, we find as many Arctic forms as in the Norwich Crag, and more than have occurred in the Chillesford Crag. In the number of individuals also the Arctic species are decidedly more plentiful, and hitherto no species having an exclusively southern range has been found in the newer deposit.*

There still remains one shell to which especial attention must be drawn; for *Tellina balthica* (Fig. 33, p. 138) appears for the first time in the Weybourn Crag, and seems to have taken possession of these seas immediately after its arrival. Thus it is usually by far the most plentiful shell on this horizon, and in many places it outnumbers all the other species put together. To anyone not intimately acquainted with East Anglian geology the stress laid by Messrs. Wood and Harmer† on the sudden appearance of this mollusc may appear to be absurdly exaggerated. But though I cannot follow them in regarding its incoming as marking a break between the Crag and the Lower Glacial deposits—for the species is not an Arctic one, and the associated fauna is characteristically that of the Crag—yet the arrival of a prolific species like this is important, and quite sufficient to outweigh a large number of records of rare shells, the finding of which depends mainly on the amount of time spent in the search.

Prof. Prestwich has attempted to account for the abundance of *Tellina balthica* in the Crag of the north-east portion of Norfolk, and its entire absence in the whole of the rest of the Norwich Crag, by pointing to the occasional absence of this species from bays on the present coast.‡ In the case of these newer Crags, however, there is no possibility of any separation of the two areas by a barrier, and if the Weybourn Crag and Norwich Crag are contemporaneous, we must be dealing with two closely adjacent

* I agree with Mr. Edgar Smith that *Astarte incrassata* of the "Cromer Memoir" is a wrong determination. The shell is *Astarte elliptica*, of which species other specimens have since been obtained.

† *See* Introduction to the Crag Mollusca; Palæontographical Soc.; and various papers.

‡ *Quart. Journ. Geol. Soc.*, vol. xxvii., pp. 471, 472. (1872.)

portions of the same shallow sea. One cannot understand how, under these circumstances, a prolific and accommodating species such as this could flourish for a series of years in one area, and yet not spread over an equally suitable district barely four miles away. The incoming of *Tellina balthica,* coupled with the marked increase of Arctic forms in the Weybourn Crag, is, I think, good evidence that we are dealing with a horizon slightly newer than the Norwich Crag.

As the Weybourn Crag is the highest division of the Pliocene series in which is found a marine molluscan fauna of any extent, this will be a convenient point at which to compare the different horizons, and to show what climatic and other changes are indicated by their respective faunas. The land and freshwater species will be more conveniently treated of in the next chapter, when we come to deal with the prolific assemblage occurring in the Cromer Forest-bed. A great discrepancy between the temperature of the sea and of the air is indicated by the fossils, and we cannot well deal with the comparatively few land animals of the Norwich Crag before the whole of the evidence has been brought forward.

*Marine Mollusca of the Pliocene Beds.**

——	Total.	Arctic.	Mediterranean.	Extinct.
Weybourn Crag - -	53	9	0	5
Chillesford Crag - -	90	7	2	14
Fluvio-marine Crag -	112	9	7	18
Red Crag of Boyton, &c.	199	13	23	55
Red Crag of Walton -	148	2	22	50
Coralline Crag - -	420	1(?)	75	169

Cast in a tabular form, the figures show at a glance the gradual refrigeration of the climate all through the Newer Pliocene period. This refrigeration may be taken as the dominant characteristic of the period, for there is a steady decrease of southern and extinct forms, and a gradual replacement by northern species, till the marine Mollusca seem to indicate conditions almost Arctic in their severity. On the other hand there is so great a resemblance of the faunas throughout, so gradual a change, and so many characteristic species range upwards into the Weybourn Crag, that we cannot without violence separate this zone from the other Pliocene deposits.

* The numbers given are only approximate. Differences of determination will probably affect each zone equally, and will not alter the comparative results.

CHAPTER IX.

CROMER FOREST-BED.

For many years the deposit now generally known as the "Cromer Forest-bed" has been celebrated, and a mere list of the papers referring to it would occupy several pages.* It will be best therefore simply to give an outline of the literature of the subject, noting all important papers, and mentioning the earliest discovery of any new fact.

Though the teeth of elephants found near Cromer were known from an earlier period, the first published notice of the Forest-bed was in 1746 by W. Arderon, in which he speaks of "the roots and trunks of trees which are to be seen at low water in several places on this coast near Hasborough and Walket [Walcot]," and also of the occurrence of fossil bones.†

It is, however, to Richard Cowling Taylor that we owe the first description of the beds. In a communication dated Aug. 14, 1822,‡ he states that "from Happisburgh, to the North of Cromer, may be traced, at intervals, along the base of the clay cliffs, a remarkable stratum containing an abundance of fossil wood and the bones of large herbivorous animals mineralized with iron. The thickness of this singular bed does not exceed two feet, and frequently not more than one. It varies in its material, from a red ferruginous sand to an ochreous coarse gravel cemented by iron." [Taylor appears only to have seen sections of the hard ferruginous conglomerate often called the "Elephant Bed."] "The stratified organic remains in the cliff of East Norfolk are buried beneath beds of blue clay, earth, and sand, from 80 to 100 feet in thickness." He also alludes to a letter by Sir Thomas Browne, written in 1659, on the head and bones of a very large fish at Hasbro,§ apparently as referring to the same deposit; but this is probably a mistake.

In another paper, in 1824,‖ Taylor, in a further description of the beds, mentions "stumps of trees rooted into the stratum," and considers the "Forest-bed" as "occupying the position usually assigned to the crag or upper marine formation;" but he also correlates the shelly gravels in the Glacial Beds with the

* For full list see Appendix.

† Extract of a letter containing Observations on the Precipices or Cliffs on the N.E. Seacoast of the County of Norfolk.—*Phil. Trans.*, vol. xliv., pt. 1, No. 481, p. 275.

‡ Fossil Bones on the Coast of East Norfolk.—*Phil. Mag.*, vol. lx., p. 132.

§ *See also* Excursions in Norfolk, 1818, vol. 1, p. 121.

‖ Remarks on the Position of the Upper Marine Formation exhibited in the Cliffs on the North-east Coast of Norfolk.—*Phil. Mag.*, vol. lxiii., p. 81, 1824.

Crag, and includes the Boulder Clay in the "upper marine formation."

Samuel Woodward, in his "Outline of the Geology of Norfolk," published in 1833, appears to have been the first distinctly to separate the Forest-bed from the Drift, but in his table of Strata he places it beneath the Norwich Crag.

Sir C. Lyell in 1840 gave a long description of the beds, but stated that he "was not so fortunate either here or elsewhere on this coast as to see the stools of trees erect in this stratum, but so many independent eye-witnesses have lately described them to me with such minuteness as to leave in my mind no doubt of the fact."*

The Rev. Charles Green, in his "History, Antiquities, and Geology of Bacton," published in 1842, gave some valuable local notes; but divided the Cromer Forest-bed into Eocene, Older Pliocene, and Newer Pliocene, and his statements are not always trustworthy. In 1845 Joshua Trimmer noticed the sand with *Mya truncata* over the Fresh-water Bed at West Runton.† Sir R. Owen, in his "History of British Fossil Mammals and Birds," published in 1846, described and figured many Forest-bed specimens.

Prof. Prestwich in 1861‡ cleared up a point which had led to great confusion in most previous papers, by pointing out that at Mundesley there are two totally distinct Fresh-water Beds,—one beneath, the other above, the Boulder Clay. This section had previously been taken as proving the interstratification of the Forest-bed and Drift.

In the first edition of Lyell's "Antiquity of Man," published in 1863, a long description of the Forest-bed is given, and he says that "Thirty years ago when I first examined this bed I saw many trees with their roots in the old soil laid open at the base of the cliff near Happisburgh." But on comparing this with his paper of 1840 it is seen that the statement must be erroneous, for in the earlier account he distinctly says that he did *not* see them. (*See* observations in Mr. Norton's paper mentioned further on.)

Mr. John Gunn in 1864, in his "Geology of Norfolk," divided the strata on the coast into Norwich Crag, Forest-bed, and Laminated Beds. Between 1865 and 1882 a series of papers was published by S. V. Wood, jun., whose classification of the deposits has already been referred to (p. 144). One of the best general diagrams of the coast between Happisburgh and Weybourn, was published by him in 1865, in a pamphlet privately printed. A valuable account of the beds was given in 1868 by the Rev. O. Fisher.§ Prof. Prestwich in 1871 gave a description of the coast

* On the Boulder Formation, or drift and associated Fresh Water Deposits, composing the Mud Cliffs of Eastern Norfolk.—*Phil. Mag.*, Ser. 3, vol. xvi., p. 345.

† *Proc. Geol. Soc.*, vol. iv., p. 435; *Journ. Roy. Agric. Soc.*, vol. vii., p. 444, 1847.

‡ On some New Facts in Relation to the Section of the Cliff at Mundesley, Norfolk.—*Geologist*, vol. iv, p. 68.

§ On the Denudations of Norfolk.—*Geol. Mag.*, vol. v., p. 544.

section, and suggested the name "Westleton Beds" for the higher portion of the Pre-glacial Series.*

In the Supplement to the Crag Mollusca by S. V. Wood, published in 1872, there is an introductory Outline on the Geology by Messrs. S. V. Wood, jun., and F. W. Harmer. Sections are given to support their view that the "Bure Valley Beds" overlie the "Forest-bed,"—the Crag beneath it, mentioned by Lyell and other writers, not having been recognised by them.

A paper by Mr. Henry Norton, only to be had as a reprint from the "Norwich Mercury" of November 5th, 1877, questioned, for the first time in print, the evidence on which the trees in the "Forest-bed" were stated to have been found rooted in the soil, and drew attention to the unsatisfactory nature of the evidence on which they were accepted as being in place. In the same year the present writer published a paper in which the *Leda myalis* Bed was separated from the Forest-bed, while reasons were brought forward to show that the latter was not a land surface; and in 1880 another short paper gave the classification adopted in this Memoir.† In 1880 Mr. J. H. Blake read an address before the Norwich Geological Society, in which he maintained the importance of the "Rootlet Bed" as an horizon, and expressed his opinion that it was the only bed showing evidence of a true land surface.

In 1882 were published the Memoirs and Sections of the Geological Survey relating to the principal portion of the Forest-bed area. These included the "Geology of the Country around Cromer," in which the Forest-bed is fully described by the writer of these pages, and a sheet of Sections of the Norfolk cliffs,‡ on too small a scale to allow the Pliocene beds to be subdivided. Mr. E. T. Newton's memoir on the "Vertebrata of the Forest-bed Series of Norfolk and Suffolk" also appeared in the same year.

A section of the "Suffolk Cliffs at Kessingland and Pakefield, and at Corton"§ was published in 1884, and also an explanatory pamphlet referring to the same area. In these Mr. Blake showed the 'rootlet-bed' alternating with laminated clays, which he referred to the Chillesford Clay, and overlying mammaliferous gravels considered to be equivalent to the Norwich Crag. During the present year (1890) a fuller Memoir appeared.‖

Since the appearance of the Memoirs, Mr. Newton and I have published a number of short papers announcing additions to the fauna and flora, or giving short descriptions of isolated sections; the titles of these papers will be found in the Appendix.

From the above outline it will be seen that our knowledge of the Forest-bed is of gradual growth, and even now such a

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* On the Structure of the Crag-Beds of Suffolk and Norfolk. Part III. The Norwich Crag and Westleton Beds.—*Quart. Journ. Geol. Soc.*, vol. xxvii., p. 452.

† *Geol. Mag.*, dec. II., vol. iv., p. 300, and vol. vii., p. 548.

‡ Horizontal Sections, Sheet 127.

§ *Ibid.*, Sheet 128.

‖ Geology of the country near Yarmouth and Lowestoft. (*Memoirs of the Geological Survey.*)

primary point as the relative order of it and the associated Crag beds is considered by some to be a debateable question. This difficulty is in great measure owing to the fact that during the summer time, when geologists generally examine the coast, the strata are almost entirely hidden by the beach, whereas it is only during the winter and equinoctial gales that clear exposures can usually be found.

Where most complete, the so-called "Forest-bed" consists of three divisions,—an Upper and a Lower Freshwater Bed, and an intermediate Estuarine deposit. The Lower Freshwater Bed is seldom preserved, though its flora is well-known from the quantity of *Pholas*-bored cakes of peat and clay-ironstone found in the Estuarine Beds, and derived from the breaking up of the underlying deposit. The relation of the Lower Freshwater Bed to the Estuarine Forest-bed seems to be somewhat similar to that of the recent "Submerged Forests" in estuaries to the deposits now forming in the same localities, in part from their destruction.

The middle division, which is more particularly the "Forest-bed" of Norfolk geologists, least deserves the name; for wherever it can be studied it is distictly estuarine, though from containing large quantities of drift wood, and especially stumps of trees, many have accepted it without hesitation as a land-surface. It is from this division that most of the large mammalian remains have been obtained.

The upper surface of these Estuarine Beds is in many places weathered into a soil and penetrated by small roots (hence the name "Rootlet Bed"*), and here and there it is covered by, or eroded hollows in it are filled with, lacustrine deposits. These form the Upper Freshwater Bed, in which most of the small bones and freshwater shells are found.

It will be seen that though a land-surface does occur in the Pre-glacial deposits, it does not correspond with the horizon to which the name "Forest-bed" has been more especially applied. It is not improbable that there may also be another land-surface beneath the *Lower* Freshwater Bed, for in one place the Weybourn Crag below the Forest-bed has a rather weathered appearance; but of this one cannot be certain. As the question whether the tree-stumps are or are not rooted in the Forest-bed has been much discussed, it will be advisable to give a brief outline of the reasons which have led me to the conclusion that they are not in their positions of growth.

Though many of the published accounts of the Forest-bed appear at first sight circumstantial, it is singular that none of the earlier observers appear to have compared the so-called soil with recent soils. If this had been done it is certain that the error which has arisen would in most cases have been avoided;

* Attention was drawn to this bed in 1870 by Prof. Prestwich (*Quart. Jour. Geol. Soc.*, vol. xxviii., p. 463); and subsequently by Mr. Gunn (*Ibid.*, vol. xxxii., p. 124), and Mr. Blake (*Geol. Mag.*, dec. II., vol. iv., p. 298).

for where the tree-stumps are embedded in clay, the clay is well laminated, undisturbed, and unweathered—which would not be the case had it been exposed to the air and to the burrowing of worms, and had thick roots forced their way into it. A second point is that in every case (and upwards of a hundred of the stools have been pulled up and examined by me at different localities) the roots do not end in small fibres, but are broken off, generally from one to three feet from the stem, and the ends are either rounded or frayed out. Taking as one of the typical instances the locality at Overstrand visited by many geologists on an excursion of the British Association in 1868, when a stool was dug up and placed in the Norwich Museum,* the writer found the bed to consist of a ferruginous quartzite-gravel mixed with some clay, and containing a large quantity of wood and many tree-stumps. None of the pieces of wood around or under the stumps were particularly rotten, as would be the case had they remained a short time in a soil on which vegetation was growing, and the bed was not weathered. Several stumps were dug out, and it was found that all the roots ended abruptly. Unfortunately the roots have been cut off the specimen in the Norwich Museum, to allow it to be placed in a case; the whole stump has, however, a battered look, unlike that of a tree-stump that had been merely silted up in its natural position.

In a few instances, in cavities between the roots of stumps but little damaged, remains of a peaty loam, such as generally forms the soil in a fir forest, are seen, and yet the matrix in which these stools were imbedded was laminated clay. Some stools have the bark preserved in hollows, while it is worn off in exposed places. It is remarkable that a large proportion of lop-sided stumps (*i.e.* stumps with all the roots growing from one side) are found. This would be inexplicable were the general description correct of the way the trees grew on the level surface of the pre-glacial soil; but when we consider them to have been drifted, it is just what might be expected, for the trees most liable to be washed away are those growing out of a steep river-bank.

For a long while the statement that the roots had been found interlacing was puzzling, but a group near Trimingham showed that this observation might be accurate, and yet the trees be drifted. In Fig. 36 the stumps *A* and *B* have their roots interlacing, and have grown together so firmly that they cannot be parted without breaking. *C* is a third stump of fir entangled with the others, but nearly upside down; it appears to have grown out of a steep bank. The extremities of the roots and stem were in each case worn or broken off, and the stools were imbedded in a mass of clay pebbles and lignite, covered by laminated clay, which had to be cleared away before the trees could be properly examined. It therefore appears that many of these stumps have probably been washed away by the wasting of the

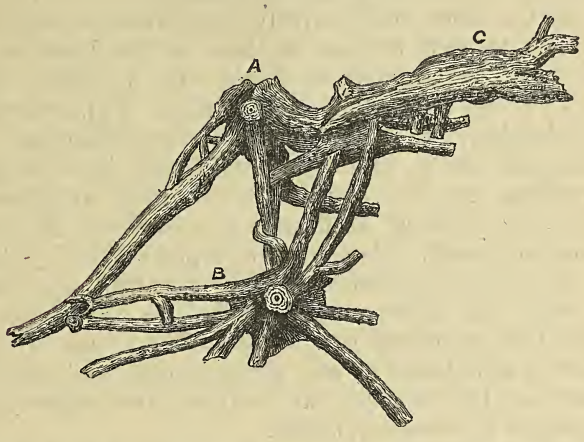
* *See* Norfolk News, Sept. 5, 1868.

river bank, and settling, generally in an upright position, as we should expect from the greater density of the roots, and from the

FIG. 36.

Plan of a Group of Trees in the Forest-bed at Trimingham.

Scale, 2 feet to an inch.



weight of the adhering soil, they have formed "snags" in the river, such as are constantly met with in streams flowing through a forest-clad country. Some of the tree-stumps may, however, be derived, like the cakes of peat, from the breaking up of the Lower Freshwater Bed.

Since the year 1882, when the Geological Survey Memoir on the Cromer Forest-bed was published, a good deal has been learnt about the Forest-bed, especially with regard to its relations to the underlying strata. The making of trial-borings in 1886 and 1888, showed that the eroded surface beneath the deposit was one of the most marked features, and that there was always a more or less gravelly base to the Forest-bed, beneath which the Crag was cut into by numerous channels or hollows. The higher deposits were so gravelly and full of water that, with the light tools used, and without lining-pipes, boring was difficult, but the base was reached in a sufficient number of cases to show the change from estuarine gravels and clays to strata of marine origin. Several of the borings were stopped by this gravelly base of the Forest-bed, and could not be carried into the Crag.

Owing to contemporaneous erosion, or to the cutting of channels after the strata were consolidated, one or more of the three divisions of the Cromer Forest-bed are often missing. Where possible the exact horizon represented in the section will be indicated in the following notes, but among such variable deposits it is not always easy to identify the different portions, even where the exposures are nearly continuous. No evidence has at present been discovered of any change of climate, or variation in the fauna and flora between the periods when the

Lower and the Upper Freshwater Beds were laid down. Certain species are doubtless known at present from one division only, but this partial distribution seems more probably to indicate mere local circumstances than any great lapse of time. Leaves of the elm and the beech, for instance, have only been found at the base of the Forest-bed Series and at one locality; these trees, however, are species generally characteristic of dry soil, and their leaves therefore could scarcely be expected to occur except merely locally in such deposits as those of the Forest-bed. On the other hand the hornbeam, maple, and hawthorn are only indicated by fruit, found abundantly in the Upper Freshwater Bed at one locality, but rare or entirely absent elsewhere. Many of the mammals also at first sight would seem to be confined to certain portions of the series; but this local distribution on further inquiry resolves itself into a separation of the large species from the small. Elephant and hippopotamus remains, for example, are almost confined to the estuarine and fluviatile gravels; voles and shrews are abundant in the Upper Freshwater Bed, but extremely rare below. The Lower Freshwater Bed seldom yields bones of any sort, for peat and peaty clays, such as are usually found on this horizon, are unfavourable to the preservation of osseous remains.

From the examples, just brought forward, of the partial distribution of the fossils, it will be understood that negative evidence is of doubtful value when an attempt is made to fix the limits in time of any one species. The elephants, or the elm and the beech, may well have ranged throughout the Forest-bed Series, though up to the present time traces of them may only have been found on one horizon. Each year additional species, formerly known from one division only, are found to range into others, and the difference between the various horizons, which in the Cromer Memoir was somewhat emphasised, is in this volume considered to be of less value than the links which bind the strata together into one set of estuarine, fluviatile, and lacustrine deposits.

It must not be thought—notwithstanding what has just been said—that the careful separation of the fossils of each zone is a matter of no importance, for unless this separation is made we shall never be able to understand, or take into account, the successive waves of migration which must have passed over the country in Pliocene times as they do in the present day. The above remarks are merely intended to prevent any reliance being placed on negative evidence, in the present imperfect state of our knowledge of Pliocene natural history. The complicated details relating to local distribution, and to the various deposits in which the species occur, could not be given in this Memoir without making it far too bulky. A considerable proportion of these details has already been given in the Cromer Memoir; the remainder is preserved in manuscript in the Office of the Geological Survey.

A summary of the more important parts of this mass of facts is given in the following pages. Selected sections are also inserted, to show the ordinary nature of the deposits, and where local peculiarities tend to modify the character of the fauna and flora these are indicated.

In describing the sections of the Forest-bed we will commence at the northern extremity of the area, for towards the south the relations of the deposits are more obscure, and there is considerable doubt as to the limits of this division.

In the neighbourhood of Weybourn the Lower Freshwater Bed appears to have been overlapped; at any rate no trace of it can there be found. The quartzite-gravels, belonging probably to the middle Estuarine division of the Forest-bed, are almost unfossiliferous, nothing having been found in them at this locality except one or two fragments of bone and pieces of wood; their mode of occurrence is shown in Fig. 34 (p. 141). Above them, for rather more than a quarter of a mile east of the Coastguard Station, there are freshwater peaty loams belonging to the Upper Freshwater Bed, lying in slightly eroded hollows cut off above by Boulder Clay, so that we cannot say whether they are portions of a once continuous lacustrine deposit, or were formed in separate ponds. Beneath these, the beds are penetrated by small roots too much decayed for microscopic examination. At one spot only could any fossils be obtained. Just five hundred yards east of the flagstaff a peaty seam yielded in abundance *Cypris browniana* and opercula of *Bythinia;* but all purely calcareous fossils have disappeared, having been dissolved by the peaty water. Shells must originally have been abundant, for a large quantity of the horny opercula were obtained by washing a little of the loam. A few yards further east the quartzite gravel rises and thins out against the Boulder Clay.

It is worthy of note that at Weybourn, under the Upper Freshwater Bed, the surface of the Chalk is irregular and much piped. In several places the Pliocene strata have subsided into hollows, but the Boulder Clay continues across undisturbed, proving the piping to be pre-glacial. East of the point where the Freshwater Beds disappear the surface of the Chalk becomes much more regular.

No further exposures that can be definitely referred to the Forest-bed occur till within a quarter of a mile of Lower Sheringham. Here we have the following section in the lower part of the cliff:—

		Feet.
Boulder Clay		
Leda-myalis Bed?	Yellowish sand and a little gravel - -	15
	Gravel - - - - - -	3
Upper Freshwater Bed (missing).		
Forest-bed (estuarine division).	Stiff dark-blue clay, with drift wood and small cakes of peat, bones and teeth of elephant, and antlers of deer.	3
Lower Freshwater Bed (missing).		
Weybourn Crag "Pan" crowded with shells - - -		1½
Chalk with flints.		

This section is interesting, because, as the Rev. O. Fisher has pointed out,* it is the most westerly exposure of the typical Forest-bed. The cakes of peat included in it also appear to point to the destruction of the Lower Freshwater Bed. The quartzite gravels, which seem nearly everywhere to form the upper part of the Estuarine division, and often overlap the clays, appear to have been at this point cut out by the *Leda myalis* Bed. From here to Sherringham the section is much obscured by talus, but one or two somewhat similar exposures can occasionally be examined, and in one place I noticed what seemed to be traces of a Pre-glacial soil. An angular boulder of felsite, 11 inches long, was obtained from the base of the Forest-bed at Sherringham; it is one of the very few instances in which igneous rocks have been found in these Pre-glacial gravels. Several masses of vein quartz and rounded boulders of quartzite nearly a foot in diameter have also been found in the Forest-bed in this neighbourhood. None of these erratics show any trace of glacial scratching.

Immediately east of Lower Sherringham, sands and thin greyish loams containing occasional specimens of *Pisidium* and *Succinea* are found. These may belong to the Upper Freshwater Bed, but more probably they represent the higher Arctic one. At this point, and wherever all the Pre-glacial beds in the cliff happen to be sandy, it is almost impossible to trace definite lines of division, but the included fossils prove without doubt that very different conditions must have prevailed during the deposition of successive portions of the sand. Where the beds are clayey there is seldom much difficulty about the lines of junction, for the older deposits generally show more or less erosion. Below this Freshwater Bed there are sands and quartzite gravels, here sometimes resting immediately on the Chalk without any intervening Weybourn Crag.

A short distance further south-east, under Beeston Hills, we have the important exposure, shown in Section 3 of the folding plate in the Cromer Memoir. Here the estuarine quartzite gravel is thin, as is the Weybourn Crag, but has yielded a few badly preserved bones. Above it we find a bed of blue-black peaty loam, for the most part rather stony. This bed is full of plant remains; but, as at Weybourn, all purely calcareous fossils have disappeared. It has yielded teeth and bones of pike, abundance of seeds, and opercula of *Bythinia*, but no shells. Among the common plants are several species of *Scirpus*, *Ceratophyllum demersum*, *Hippuris vulgaris*, *Rumex maritimus*, *Potamogeton heterophyllus*, *P. trichoides*, *P. pectinatus*, *Chara*, &c. Resting on this Upper Freshwater Bed there is gravelly sand with occasional marine shells, perhaps only derivative, above which is found the Arctic Freshwater Bed. At a point mid-way between the Hill and the Stream all the beds are fossiliferous, and the following section is shown; the beds con-

* *Geol. Mag.*, vol. v., p. 545. (1868.)

tinuing with the same character for a considerable distance both east and west, though the thicknesses vary slightly :—

		Feet.
Boulder Clay.		
Arctic Freshwater Bed	Sand and loam. Peaty laminated loam with *Salix polaris* and moss	7
Leda myalis Bed?	False-bedded sand and sandy flint gravel with a few marine shells	4
Upper Freshwater Bed	Peaty loam with opercula of *Bythinia tentaculata*, seeds, and fish bones	5
Forest-bed (estuarine division)	Clay, quartzite-gravel, and sand, with occasional fragments of mammalian bone	6
Lower Freshwater Bed.	(missing).	
Weybourn Crag	Pan and stone bed, with clay, clay-pebbles, and marine shells: *Purpura lapillus*, *Littorina littorea*, *Cardium edule*, *Astarte compressa*, *Cyprina islandica*, *Tellina balthica*, *T. obliqua*, *Mactra ovalis*, *Mya arenaria*	1
Chalk with flints.		

The exposure at Beeston is particularly important in showing clearly the succession, for all the beds between the Boulder Clay and the Chalk are represented, with the exception of the Lower Freshwater Bed. At the time this section was noted the cliff was exceptionally free from talus, for the erection of groynes at Sherringham had caused the beach to be thoroughly cleared away for some distance to the south-east.

A few yards from the stream at Beeston the Pliocene strata are cut out by Boulder Clay, and when they reappear half a mile further south-east the Freshwater Bed is missing, and the estuarine division of the Forest-bed cannot definitely be recognised.

On the west side of West Runton Gap (sometimes called Woman Hithe), there occurs at the base of the cliff a mass of blue clay, belonging probably to the Forest-bed, which, when traced towards the Gap, becomes whitish and weathered, and near the road is penetrated by small roots. Here it is immediately overlaid by marine sands with *Leda myalis* and *Mya truncata*, in the position of life ; but in the centre of the roadway a thin seam of peaty sand full of freshwater shells intervenes, and the clay is penetrated by small roots (Rootlet Bed). Within 50 yards the Freshwater Bed is again cut out by the *Leda myalis* Bed ; nevertheless a continuous weathered soil can now be traced for at least half a mile. About 150 yards south-east of the Gap the Freshwater Bed reappears, resting on an eroded surface of weathered laminated clay and sand with marine shells. It now continues without interruption for 350 yards, with a maximum thickness of about six feet.

The Upper Freshwater Bed at Runton consists of peat or peaty loam with generally a sandy or clayey base ; and from this locality most of the small vertebrate remains, and the freshwater shells, in public and private collections, have been obtained. In the Appendix is a full list of the fossils ; but as the species vary according to the nature of the deposit, it is desirable to draw attention to the characteristics of each portion.

Near West Runton Gap the bed is a loamy sand full of *Corbicula fluminalis* and *Paludina gibba*, but does not exceed eight inches in thickness. Where it reappears further east it is also sandy, especially at the base; and if this sand is carefully sifted it yields in abundance bones of small mammals, birds, reptiles, amphibia, and fishes, and numerous freshwater shells. Unfortunately the extraordinary abundance of small bones in this part of the deposit was only discovered when the bed was to a large extent hidden by talus, though for several months previously it had been well exposed. There is also a great variety of mollusca, including several species which are either extinct or not now living in England; the former are *Limax modioliformis*, *Paludina gibba*, and *Hydrobia runtoniana;* the latter include *Corbicula fluminalis*, *Hydrobia Steinii*, and *Valvata fluviatilis* (see Pl. V.). Still further east the base of the bed is clayey, with abundance of *Hydrobia runtoniana*, and the upper part is peaty with large *Anodons*, elytra of beetles, and badly preserved seeds. Bones occur throughout, though, when found in the wet peaty portion, they are generally much decayed. Mixed with the perfect land and freshwater shells a few worn and decayed fragments of *Tellina balthica* and *Cardium edule* have been found, evidently derived from the underlying estuarine beds. To the same cause we should refer the occurrence of a tooth of a seal; for there is not the slightest evidence of the irruption of the sea at this stage, the other fossils being purely lacustrine and fluviatile. A single rolled fragment of an elephant's tooth has been found, but as none of the other bones are water-worn, and no other specimen of elephant is known from this horizon, this also is probably derivative.

The roots which penetrate the underlying soil are here always too much decayed for microscopic examination, but from their shape and mode of growth they probably belong to pine or fir. When the pine grows on an alluvial soil saturated with water all the main roots spread horizontally to form a sort of platform, sending off a mass of small roots of nearly equal size vertically downwards. At Runton it seems that the stools have been washed away, leaving only the termination of the roots, but at the same horizon at Happisburgh one stool was found in the soil; and a root examined microscopically showed obscure traces of what appeared to be coniferous structure, but it was too much decayed for satisfactory determination.

The clays and gravels which form the soil on which these trees grew, here belong to the estuarine division of the Forest-bed; but, unfortunately, the junction between it and the Weybourn Crag is for considerable distances hidden by the beach, and in many places it cannot definitely be said to which division an isolated exposure may belong.

Beneath the Freshwater bed laminated loam with *Tellina balthica*, and pebbly quartzite gravel, have weathered into a soil in the upper part, but are well bedded two or three feet down.

These pebbly gravels, which are common all along the coast, are often cemented into a mass of ferruginous conglomerate, which, after the talus has been cleared away by storms, forms a conspicuous tabular mass at the base of the cliff, or on the foreshore. This "pan" or "elephant-bed," as it is often called, lies on no fixed horizon, but ranges throughout the Forest-bed, sometimes at the base, but more commonly high up. It appears always to occur at the base of a mass of gravel or sand which rests on impervious clays.

Tracing the strata from West Runton Gap, the first characteristic section of the estuarine beds that has been observed is a short distance west of the large Chalk boulders in the cliff. Here laminated clay full of lignite occupies a hollow eroded in the Weybourn Crag and cutting nearly to the Chalk, but a few yards further it rises and is lost in the beach. Under the western end of the first Chalk boulder, the Freshwater bed again appears in the cliff for about ten yards, resting on weathered loamy gravel with estuarine shells.

Near Wood Hill there is shown on the foreshore a bed of clay-pebbles resting apparently on an eroded surface of Weybourn Crag. This bed passes up into alternating laminated clays, sand, and gravel. All the beds contain much drift wood and occasional derivative cakes of peat. Bones, and marine, land, and freshwater shells, occur abundantly near the base. Owing to the peculiar nature of this deposit, which has been formed in part from the breaking up of the Weybourn Crag and of the Lower Freshwater Bed, it is very difficult to say to what extent the marine shells may be derivative, but most of the land and freshwater species certainly belong to the bed; and so do many of the estuarine forms, for there are seams full of mussels in the position of life.

These beds of clay-pebbles maintain the same character for some distance south-east of East Runton Gangway; they are extremely fossiliferous, and show better than any other portion of the deposit the curiously mixed or estuarine character of the typical Forest-bed fauna. Mr. A. C. Savin, of Cromer, has here obtained a number of mammalian remains. Among those found in the course of the Survey were—the scapula of elephant, jaw of *Trogontherium* (Fig. 37), and antlers of several species of deer, now in the Museum of Practical Geology. The *Trogontherium* is a large extinct rodent allied to the Beaver; it is common in Upper Pliocene freshwater deposits. The quantity of bones seen at Runton indicates that at present this is one of the best localities for collecting from the estuarine division. It is also the only place where land-shells are found in any abundance; *Helix* is particularly common, much

Fig. 37.

Trogontherium Cuvieri, Owen (*lower grinders, from a specimen found at Mundesley*).

Natural size.

more so than any freshwater species. In the list of species in the Appendix, those which may be derivative are marked as doubtful, but it is worth notice that some of the characteristic Crag forms undoubtedly belong to the bed. Among these may be mentioned the well-known Norwich Crag fish, *Platax Woodwardi* (Fig. 38), here very common, and occurring, though more rarely, in the Weybourn Crag. *Melampus pyramidalis*, an extinct Crag shell, is also more abundant than in the older beds. *Tellina obliqua*, *Nucula Cobboldiæ*, and the reversed *Trophon antiquus*, are plentiful, but may be derivative. The whole of the marine species occur also in the Weybourn Crag; the more abundant forms are such as we find thrown up on sandy beaches at the mouths of estuaries (*Cardium edule*, *Mytilus edulis*, *Donax vittatus*, *Littorina littorea*, *L. rudis*, *Purpura lapillus*, *Melampus*).

FIG. 38.

Platax Woodwardi, Ag., *from the Forest-bed at Runton.*

Natural size.

Mixed with the shells a few stools of trees were observed, and in one place a trunk of fir over 18 feet long: but, as a general rule, the drift wood and shells occur in distinct beds, for heavy rains would wash trees into the estuary, at the same time damming back the tide, while on other occasions storms would wash in marine shells from the open sea. Thus the alternation of beds of lignite with marine sands does not necessarily point to any change of level during their formation. Besides the little-altered drift-wood, derivative pebbles of lignite, jet, and very rarely of silicified wood, were found.

On both sides of East Runton Gangway a mass of the ferruginous conglomerate locally termed "pan" forms a conspicuous feature at the base of the cliff. The beds immediately beneath could not be examined at this spot; but at the foot of the beach (about 7 feet below the base of the pan) the bed of clay pebbles is often well shown, and contains an unusual abundance of antlers of deer, belonging to at least three species. Several elephants' teeth have been found here, but they were too much decayed for preservation. A few yards east of the Gap a boulder of coarse greyish granite, measuring $2 \times 1\frac{3}{4} \times 1$ feet, was to be seen among the clay-pebbles and bones; the rock was composed of orthoclase, quartz, muscovite, and a little hornblende. This is by far the largest boulder yet found in the Forest-bed, and is also one of the very few of igneous origin yet noticed, but it is impossible to say from what district the mass had been derived. A few bones occur in the pan, but they are usually much broken. As a general rule, for all localities of the estuarine division of the Forest-bed the least damaged specimens have been obtained from clayey beds, but they usually need careful handling and gelatinising; the bones from the pan or elephant-bed are harder but

more broken and worn. In the clays most of the bones occur in masses of rolled clay-pebbles, and very few in the laminated portion, though one or two found in the latter are unusually perfect.

Between East Runton and Cromer the estuarine Forest-bed can only here and there be seen at the base of the cliff or on the foreshore; it appears gradually to become more carbonaceous, and contains few marine shells, except mussels. About three-quarters of a mile north-west of Cromer there is sometimes exposed at low water two or three feet of black mud representing the Lower Freshwater Bed. This mud can be traced for about a hundred yards, cutting through the Weybourn Crag, and in one place for a few feet touching the Chalk, so that it extends to extreme low water mark. Resting on and overlapping it greenish laminated sandy clay full of wood contains occasional marine shells and fir-cones. This exposure of the Lower Freshwater Bed is especially important, as being one of the few places where the horizon has been examined *in situ*; though from derivative boulders in the overlying estuarine beds, and from beach specimens at Happisburgh, its flora is fairly well known. The deposit is a tenacious and carbonaceous river-mud with fish-bones, and abundance of seeds of water and marsh plants and masses of the bracts of cotton grass.

Opposite Cromer the Forest-bed is hidden under the sea-wall and by the beach retained by the groynes, but a few yards west of the wall, laminated clay with drift-wood and fir-cones is occasionally to be seen at the base of the cliff and on the foreshore. Many tree-stumps are said to have been found when the sea-wall was being built, but now no clear sections are met with till the last groyne is passed. On the lower side of the groyne, when the beach has been scoured away by storms, clayey gravel is laid bare. From this locality Mr. Savin has obtained many bones.

Between the Lighthouse Hills and Overstrand village the Forest-bed changes very little. In the upper part it consists of laminated blue clay with drift wood, but (as far as the writer has seen) no bones. Beneath there are generally alternations of clay and gravel with large pieces of drift-wood, bones, and mussels; and at the base is found a bed of clay-pebbles with abundance of bones, resting on the fossiliferous clays of the Weybourn Crag. The thickness of the Forest-bed near Overstrand appears to average about 15 feet; in one place it measured 24 feet.

A large proportion of the mammalian remains in old collections were obtained from the Green Hill Rocks, opposite the lighthouse. Several hundred elephants' teeth must have been found, and yet probably the locality was not exceptionally fossiliferous. The reason why so many bones have been washed out is that the building of the jetty and groynes at Cromer stopped the travelling of the beach, so that for many years these rocks were

continually bare. They have now been much denuded, and fewer fossils are obtained, but several teeth of elephant, a jaw of *Trogontherium*, and various other bones were found during the Survey. Mr. A. C. Savin has a large collection from this locality, and the majority of Miss Anna Gurney's specimens, now so widely distributed, came from here. Tree-stumps scattered throughout the beds are very common, but comparatively few trunks are seen. Most of the stools belong to fir or pine of moderate size; other trees, except willow, are rare. There are also many derived cakes of peat, often bored by *Pholas*, with elytra of beetles and leaves. In isolated exposures the clays of the Forest-bed may be distinguished from those of the Weybourn Crag by their dark blue colour, the latter being greenish.

One or two sections will give an idea of the general character of the beds, the details of which vary slightly every few yards. The following was taken nearly under the Old Lighthouse :—

		Feet.
Boulder Clay.		
Leda myalis Bed (?)	Sand with a little loam, a few stones in the lower part	6
Upper Freshwater Bed.	(missing).	
Forest-bed (estuarine).	Laminated clay and lignite	12
	Alternating gravel and clay with a few seams of mussels and much lignite	7
	Clay-pebbles, with lignite, cakes of peat, and mammalian bones	3
Lower Freshwater Bed.	(missing).	
Weybourn Crag.	Greenish loam, clay, and clay-ironstone, full of casts of marine shells	(?)

Not far from this spot the *Pholas*-bored peat of the Lower Freshwater Bed was found in place during October 1889. The mass preserved was apparently only a few square yards in extent and not more than ten inches thick. It distinctly lay between the Weybourn Crag and the bed of clay-pebbles forming the base of the estuarine division.

At the eastern end of Kirby Hill the Boulder Clay had cut several feet into the Forest-bed, and the mass of bedded blue clays shown further west had disappeared. On the foreshore, about mid-way between these exposures, lying on and partly embedded in the clay-gravel was a stump of fir, 3 feet in diameter near the base, with the roots spreading over 11 feet in one direction, and 9 feet in another. In hollows there were here and there preserved portions of the bark, and also of a loamy peaty soil with seeds. This was by far the largest tree examined; for it had a spread of about 20 feet; no other having exceeded 10 feet. By employing men to clear away the clay, I was able examine the termination of many of the roots; they were all worn, and one, which was traced for a long way among the clay-pebbles, measured about 3 inches at its broken and rounded

extremity. It was cut off, and is now in the Museum of Practical Geology as an example of the ordinary worn state of the roots in the Forest-bed trees.

At Beck Hithe the Boulder Clay cuts deeply into the Forest-bed, and the bones, though abundant, are much crushed and decayed. A few yards to the east the junction again rises, and the Upper Freshwater Bed appears immediately beneath the Boulder Clay. The exposures between Overstrand and Sidestrand being fully described in the Cromer Memoir, one characteristic section will be sufficient to indicate the nature of the deposits, for though the thickness varies considerably the general character of the strata remains unchanged for some distance. About 600 yards east of Beck Hithe, the following section was seen; its exact position may be found by the enormous Chalk boulder in the cliff above, and by the old groyne on the shore opposite :—

		Feet.
Boulder Clay.		
Upper Freshwater Bed.	Sand irregularly mixed with carbonaceous blue clay: *Valvata piscinalis*, *Bythinia tentaculata*, *Pisidium amnicum*, *Unio* or *Anodon* -	2
Forest-bed (estuarine).	False-bedded sand with clay-pebbles and fragments of *Mytilus*. (A perfect specimen of *Scalaria grœnlandica*) - - -	4½
	False-bedded sandy gravel, in places cemented into pan - - - -	4
(?)	Hidden under the beach - - -	4
Weybourn Crag.	Sandy clay with decayed marine shells.	

Beneath the Freshwater Bed there are perhaps some small roots penetrating the estuarine sands, but they are obscure and much decayed. A sample of the carbonaceous clay, recently obtained a few yards from this spot, yielded a number of seeds, belonging as usual to marsh and aquatic plants, but among them were also some fruit of hawthorn, a species not previously found in the Cromer Forest-bed.

Under the high cliffs at Sidestrand the Upper Freshwater Bed increases in importance, and becomes a bedded lacustrine clay full of shells, seeds, and fish-bones. Mammalian remains are scarce, and land-shells are seldom found in it; so that both the nature of the deposit and the included fossils point to a shallow lake, bordered probably by marshy ground, and a thick belt of sedges, which strained out any land shells or drift wood. Thus the whole of the animals and plants here found are aquatic or marsh species, and the fauna and flora, though the plants are here in a better state of preservation, are not so interesting as at West Runton, where land-mammals and mollusca are abundant, and forest trees occur. The commonest plants at Sidestrand are the floating pondweeds, yellow water-lily and water-crowfoot. The water-chestnut occurs, but is extremely rare. Most of the other plants belong to wet meadows ; among

them are various sedges, docks, and the buttercup. The mollusca call for no remark, since they are all, except *Hydrobia marginata*, common species at the present day in Norfolk. The following section of these deposits was seen at the foot of the cliff about 100 yards south-east of Sidestrand Church; two measurements were taken 15 yards apart:—

		Feet.
Boulder Clay, with uneven base.		
?	False-bedded sand with thin blue clays and a little carbonaceous matter	3½ to 7
Upper Freshwater Bed.	Blue bedded clay, the lower part stony: *Pisidium amnicum*, *Unio* or *Anodon*	4 to 3
	Gravelly blue clay with *Unios*	0 to 1
Forest-bed (estuarine).	Ferruginous loamy gravel, with *Mya truncata* and *Tellina balthica* in the position of life	1 to 0

A few feet in each direction the gravel with *Mya truncata* cannot be found; it is apparently cut out by the Freshwater Bed. In one place the shell of the *Mya* has been entirely dissolved away, but the tough siphon-tubes are well preserved, looking much like portions of decayed roots of trees.

The Freshwater Bed can now be traced continuously for about 320 yards, when it is suddenly cut off by the Boulder Clay. As it constantly shows slight variations, one detailed section must here suffice. At 180 yards north-west of the trough occupied by Boulder Clay the subjoined strata were observed in the course of the Survey:—

		Feet.
Boulder Clay.		
Leda myalis Bed?	Sand and thin clays	2
Upper Freshwater Bed.	Laminated loam	1
	Blue carbonaceous clay, bedding obscure	3½
	Blue stony loam, with freshwater shells, seeds, and drift-wood	1
Forest-bed (estuarine).	Clayey pan, with driftwood (*Mya* not observed, but may have entirely decayed)	1½
	(Strata hidden by beach)	4
	Laminated clay, clay pebbles, lignite and a few bones	1+

A few yards from this spot an attempt was made to reach the Weybourn Crag by boring, but without result, as the Forest-bed was gravelly and sandy and full of water. The boring commenced in the blue clay at the base of the Upper Freshwater Bed and penetrated the strata marked as "hidden" in the last section; these consisted of black gravelly sands.

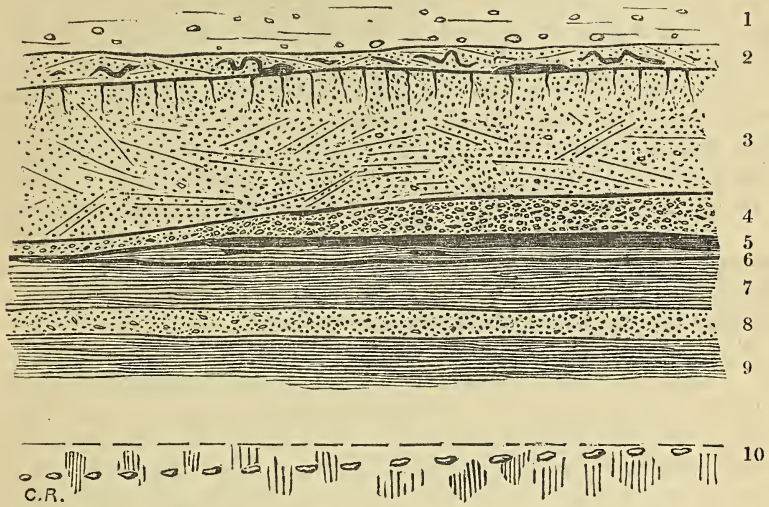
For nearly half-a-mile no sections can be seen, for the Boulder Clay cuts through the beds to beneath the sea-level. When the Pliocene beds reappear, the character of the upper portion of the section has a good deal altered.

At 100 yards south-east of the old groyne at Trimingham (there is no other landmark visible by which to fix the spot) we have the section shown in Fig. 39.

Fig. 39.

Section of the lower part of the Cliff near the old Groyne at Trimingham.

Scale, 20 feet to an inch.



Contorted Drift?	1.	Hard blue stony Boulder Clay (base only shown).
Upper Freshwater Bed.	2.	False-bedded sand, irregularly mixed with carbonaceous blue clay.
Forest-bed (estuarine).	3.	Fine loamy bluish false-bedded sand, with very few stones, the upper part penetrated by roots (Rootlet Bed).
	4.	Clay pebbles, gravel, sand, and lignite, with numerous bones.
Lower Freshwater Bed.	5.	Carbonaceous green clayey silt, full of seeds.
	6.	Laminated lignite and loam.
Weybourn Crag.	7.	Green and blue laminated rather carbonaceous clay.
	8.	Sand with marine shells.
	9.	Clay as above.
Upper Chalk -	10.	Probable position of the Chalk.

At the time the strata were examined the beach had been entirely swept away by a storm, and a continuous exposure could be traced to low-water mark. All three divisions of the Forest-bed were well shown in vertical section, and the total thickness of the Pliocene beds must be about 40 feet. A broken line has been put in to show the probable position of the Chalk, but it may perhaps be a few feet lower.

The Upper Freshwater Bed in the section just figured, and in numerous others which have been or will be described, shows a peculiar structure, the carbonaceous clay and sand being apparently contorted together. At first sight, one might suppose this to be connected with the contortions in the Boulder Clay; but in numerous instances these small contortions in the Freshwater Beds are cut off and overlain by evenly-bedded freshwater clays, proving that they originated contemporaneously with the deposit. A similar contorted structure is not uncommon in

recent alluvium, and may originate in various ways. An elephant, hippopotamus, or other large animal treading in the shallow water would easily squeeze the clays into these shapes. One may notice that the oxen and horses standing on the shores of the Broads often force up black mud through the gravel on each side of their footprints. Another mode of accounting for the contortion is that it is due to the lateral thrust caused by the alternate freezing and thawing of the beds in the winter. But in either case it is noticeable that in the well-laminated fresh-water clays that are found at Sidestrand and a few other places, and which appear to have been formed in water too deep for freezing, or disturbance by the growth of water-plants, no contortions are found. In the contorted beds the common mollusca are the almost amphibious *Succinea*, *Limnæa peregra* (*L. limosa*), and *Pisidium pusillum*, while in the bedded clay of Sidestrand the more lacustrine *Ancylus* (*Velletia*) *lacustris* is perhaps the most abundant species.

The Lower Freshwater Bed is now cut out, but for a quarter of a mile to the south-east, beyond slight variations in the relative thickness of the different deposits, there is no other change and the small roots can be seen about 8 feet above the beach wherever the section is free from talus. At about three furlongs south-east of the old groyne at Trimingham the three tree stumps shown in Fig. 36, p. 151, were found. The section is:—

		Feet.
Boulder Clay.		
Upper Freshwater Bed.	False-bedded sand, with irregular seams of grey loam and a gravelly base	2
Forest-bed (estuarine).	False-bedded sand, with a few seams of loam and scattered pebbles	5½
	Laminated and false-bedded sand and clay	1½
	(Strata hidden by beach)	4
	Clay-pebbles and pan, with tree-stumps and lignite	2
	Blue laminated carbonaceous clay, lignite, and clay pebbles	3+

About 200 yards further south, the bed of clay-pebbles which contains the tree-stumps yielded a jaw of cod, the only marine fossil noticed in the Forest-bed in this neighbourhood, except a tooth of the sperm whale (*Physeter macrocephalus*).

The false-bedded sands now gradually change to laminated clay, which forms a conspicuous mass 6 feet thick at the base of the cliff under Trimingham lime-kiln. About 50 yards further south the mass of laminated clay has been cut out and replaced by sand and loam. Then the Boulder Clay gradually descends and cuts out the Freshwater Bed, but the Estuarine division can be traced to near the western Chalk bluff at Trimingham. There are continual variations, but it is unnecessary to note every change. The last section which could be seen was 80 yards from the Chalk. Unfortunately persistent talus prevents us from tracing the beds till they disappear in the glacial contortion

which has forced the Chalk above its normal level, and it is at present doubtful how they end off. Pliocene deposits will not improbably be found beneath the Chalk, which is here contorted into a loop and inverted. The Chalk cannot have stood at its present high level when the Forest-bed was deposited, for the laminated clays are seen close to the Chalk without containing any fragments of it. A small hill of this sort would have entirely disappeared long before the whole of these Pliocene strata could have been laid down, for the Chalk is exceptionally soft, and it would have been always exposed to atmospheric action and the constant washing of peaty water. It has been stated that Crag occurs on the top of these Chalk bluffs; but this is a mistake; the shelly sand there seen is merely a patch of the ordinary Glacial sand.

An attempt was made to settle the relations of the strata by boring close to the southern face of the bluff; but this only proved that at least 10 feet of Glacial sands pass under the contorted Chalk, for at that depth boring was stopped by quicksand, without reaching Pliocene strata.

On the south-east side of the bluff the Forest-bed reappears within 140 yards, and as the base of the Boulder Clay is there a few feet higher than on the north-west side, the Upper Freshwater Bed is again seen. At 180 yards from the Chalk the following section occurs :—

		Feet.
Boulder Clay.		
Upper Freshwater Bed.	Sand and blue loam mixed	1
	Sand irregularly mixed with blue clay: *Succinea* throughout	2½
	Blue bedded carbonaceous clay with seams of sand and a few small stones; twigs and shells throughout, *Succinea putris* very common, *Cyclas cornea* one valve	2½
	Contorted laminated clay and sand, with a little gravel and a carbonaceous seam at the base	2
Forest-bed (estuarine).	Well-bedded blue clay with a few thin seams of gravel and sand	4½
	Bedded sand and clay	1+

The perfectly undisturbed stratification of the Pliocene strata at this spot is remarkable, for not only is the Chalk in the cliff on each side much folded, but the foreshore immediately opposite the section above noted is occupied by highly disturbed glacial deposits and Chalk, which at one point appear to overlie the carbonaceous clays of the Forest-bed. It is possible that in the last section we may have both the Arctic and the Upper Freshwater Beds; but at the time this exposure was noted the writer was unaware of the distinction, and for the last ten years this part of the cliff has been too obscure for detailed re-examination. At 180 yards beyond the south-eastern Chalk bluff pan is seen at the top of the beach, but no clear exposure occurs for 130 yards further. From the reappearance of the

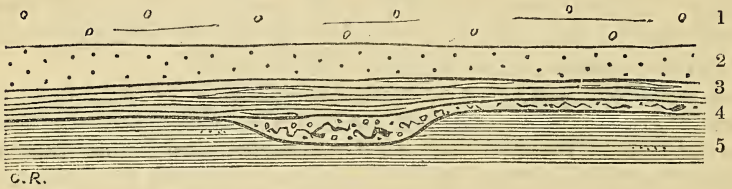
beds half-a-mile north-west of Mundesley Church, to Mundesley village, an almost continuous section has been examined, though the whole of the cliff is never free from talus at one time, as landslips occur immediately the buttresses are washed away.

About 200 yards from the first exposure there was the section shown in Fig. 40.

FIG. 40.

Section of the lower part of the Cliff three quarters of a mile north-west of the Coast Guard Station, Mundesley.

Scale, 20 feet to an inch.



2nd Till	-	1. Blue Boulder Clay, very chalky.
Arctic Freshwater Bed		2. Sand. 3. Bedded blue loam, full of moss and seeds; *Salix polaris*, *Betula nana*. 4. Blue loam mixed with gravelly sand, filling an eroded hollow; *Succinea*.
Forest-bed (estuarine).		5. Laminated clay.

In the Cromer Memoir horizons 3 and 4 were referred to the Upper Freshwater Bed, but the discovery that they contain leaves of the Arctic willows and birches proves that the correlation was erroneous. The Upper Freshwater Bed is probably entirely missing between the Chalk bluffs at Trimingham and the stream at Mundesley.

About a quarter of a mile to the south-east of the point where the strata shown in Fig. 40 were observed, the Forest-bed is full of derivative cakes of peat from the Lower Freshwater Bed, and also proves its estuarine origin by occasional seams of mussels. The lithological character of the Forest-bed changes continually; but as these variations are only such as occur in most estuarine beds, it is unnecessary to give all the details. Three furlongs north-west of the Coast Guard Station, Mundesley, the base of the cliff is a mass of laminated clay with thin seams of sand; but within 70 yards it has entirely changed, by the gradual thinning out of the clays, to false-bedded sand. This variable character in the strata continues to Mundesley, where on the foreshore, in beds rarely uncovered, many mammalian bones have been found, including three jaws of *Trogontherium*, now in Mr. Fitch's collection. The beds in the cliff yield comparatively few specimens.

The relations of the different deposits at Mundesley are somewhat difficult to make out. Great care is also needed to prevent confusion of the fossils from the different freshwater deposits;

for at Mundesley there is a Post-glacial bed, which cuts into the Forest-bed; and the Arctic, the Upper, and the Lower Freshwater Bed also occur. The general section of the lower part of the cliff is :—

2nd Till.	Boulder Clay, very chalky.
Arctic Freshwater Bed.	Sands with freshwater shells, and clays with Arctic plants : *Salix polaris*, &c.
Leda myalis Bed?	Sands and clays, perhaps marine.
Upper Freshwater Bed.	Blue peaty clay, full of *Unios*, seeds, and fish-bones (local patches only).
Forest-bed (estuarine).	Laminated clay and sand, with beds of mussels.
	Gravel, clay-pebbles, lignite, mammalian bones, and cakes of peat bored by *Pholas*, representing the destroyed Lower Freshwater Bed.

At this locality all the beds are fossiliferous, and can be seen in vertical succession after storms have cleared away the talus. The Upper Freshwater Bed is thin, and only preserved in small patches, which occur at about two feet above the beach on the south-east side of the village, for about 60 yards beyond the broken sea-wall. The bed rests in slightly eroded hollows in the estuarine clays of the Forest-bed, and does not exceed six or eight inches in thickness, though it is very fossiliferous. At one spot the clay beneath it is weathered white, and shows obscure traces of roots. Derivative fragments of *Tellina balthica* and *Cardium*, and a *Balanus* with the valves united were washed out of the Freshwater clay, mixed with perfect specimens of *Valvata* and *Ancylus*.

The contemporaneous fossils of this thin seam are like those found at Sidestrand, but the locality is more prolific, and has yielded a larger number of species, though a less quantity of the clay has been minutely examined. The vertebrata are only represented by the vole, frog, and three or four species of fish, large mammals being absent, as is often the case on this horizon.

The underlying estuarine beds contain a number of bones of large mammals, principally elephant, rhinoceros, and deer; many specimens being found every year, though the principal fossiliferous horizons are only occasionally laid bare.

Till lately I had never been able to examine the strata hidden by sand on the lower part of the foreshore at Mundesley, though down to half-tide level they were occasionally visible. It was thus quite unexpectedly that on boring through a platform of hard gravel at mean-tide, the soft loams of the Weybourn Crag or Chillesford Clay were immediately entered (*see* p. 137). This proved that the Forest-bed Series was here thinner than had been imagined, and also accounted for the absence of ledges near low-water; for the loams are much too soft to form ledges, and are scoured away directly they are laid bare.

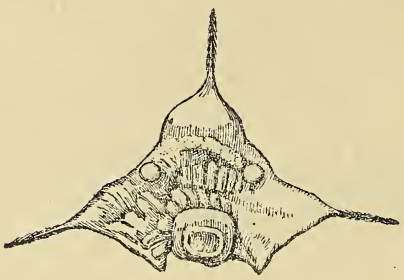
For some distance south there is no change of importance in the lithological character of the estuarine beds. At a quarter of a mile south-east of the sea-wall, immediately above the beach,

a number of large derivative cakes of peat was found in the quartzite-gravel; these were all bored by *Pholas*, and contained large quantities of the peculiar fruit of the water chestnut (*Trapa natans*) (Fig. 41), a plant only known in other parts of

Fig. 41.

Trapa natans, Linn. (*fruit*).

Natural size.



Britain by specimens from the Forest-bed. From the similar contents of the different cakes at any one place, it was probable that they had not drifted far, but till lately the Lower Fresh-water Bed was unknown in place near Mundesley. North-west of the village another accumulation of derivative cakes of peat was seen, but all the masses were composed of reeds, *Trapa natans* being absent. During October 1889 the deposit was discovered in place at half-tide level, 550 yards south of the stream. It is a black laminated peat, crowded with fruit of *Trapa natans* and opercula of *Bythinia*, but no other fossils were obtained, except a single specimen of *Ceratophyllum demersum*. The surface of the peat is bored by *Pholas*.

When the beach between Mundesley and Bacton has been cleared away by north-westerly gales, large quantities of bones are obtained, just below high-water mark, in alternating beds of clay-pebbles, laminated clay, and gravel with drift-wood and tree stumps. These beds extend to the foot of the beach, but sand-banks usually obscure the whole of the foreshore. The fossils obtained are generally bones and teeth of *Elephas meridionalis* and *E. antiquus*, and antlers of deer; but probably here, as elsewhere, the scarcity of small specimens is largely owing to the little demand for them. An elephant's tooth has a definite price, but most collectors care little for the smaller things; and the long-shore men, when they notice them at all, find them so difficult to handle without breaking as not to be worth the trouble of preserving.

About 500 yards from the sea-wall a perfect femur of elephant, 5 feet in length, was found partly imbedded in the upper surface of the estuarine division of the Forest-bed. This specimen, now in the collection of Mr. Colman, at Corton, is remarkable both for its perfect preservation and for the unusually high position

4 feet above the beach, in which it occurred. The bones are here generally found in a bed about 5 feet lower, seen on the foreshore opposite.

Half a mile from Mundesley the jaw of glutton, figured by Mr. E. T. Newton,* was found about high-water mark. Nearly a mile from Mundesley mussels are found in the Forest-bed; thus proving that the strata are still partly of marine origin. About three-quarters of a mile south of Mundesley the Lower Fresh-water Bed was again seen for a few yards. It here consisted of peat full of matted reeds, seeds of bog-bean, and elytra of beetles, but *Trapa natans* was not found.

At a mile and a quarter from Mundesley the Till suddenly ploughs through the beds to beneath the sea-level, but just north-west of the point where the Forest-bed disappears the subjoined section was observed:—

		Feet.
2nd Till	Boulder Clay, very chalky.	
Forest-bed (estuarine).	Laminated clay and sand	5
	Beds of clay-pebbles, with *Mytilus*, *Littorina*, *Balanus*, teeth of *Arvicola*, and limb-bone of *Trogontherium*	2

For nearly half a mile south of this point no sections are to be seen, but where Pliocene strata reappear the character is unaltered. About 80 yards further they become more gravelly, and show false-bedding with a northerly dip. The gravel is composed of nearly unworn flints, and flint, quartz, quartzite, clay, and clay-ironstone pebbles, with rarely cherty sandstone (Neocomian?), green coated flints (Eocene), pyrites containing wood, and jet; there is also a little drift wood, some cakes of peat, and small selenite crystals. The only fossil found was a fragment of elephant's tusk about 5 inches in length.

In the neighbourhood of Bacton the Forest-bed shows extremely rapid changes in lithological character; and as the upper part rises 10 or 15 feet above the level of the beach, it can easily be examined, and may be described generally as a mass of false-bedded gravel and sand with lenticular seams of laminated clay, clay-pebbles, or lignite. A few sections taken here and there will be sufficient to show the ordinary character of the deposits.

At 350 yards north-west of the first road to Bacton village the following section was noted:—

		Feet.
Soil		1½ to 2
Valley Gravel	Gravel and loam contorted together, and squeezing up the laminated clays of the Forest-bed	7
Forest-bed (estuarine).	Laminated clay and sand, with a bed of wood at the base	8
	Clay-pebbles and gravel, with large unworn flints, quartzite pebbles, &c. Nnmerous mammalian bones	3
	Laminated clay, clay-pebbles, and lignite	3

* *Geol. Mag.*, dec. II., vol. vii., p. 424 (1880); and The Vertebrata of the Forest Bed Series (*Memoirs of the Geological Survey*), p. 17.

Between this point and the road the beds are very sandy and gravelly. The composition of the gravel is:—

Unworn and sub-angular flints	82
Quartzite pebbles (often large)	73
Flint pebbles	56
Quartz	32
Hard sandstone (Neocomian ?)	6
Chert	2
Black grit	2

Close to the site of the old Coast Guard Station at Bacton (marked on the Map) marine shells are met with for the last time as we trace the strata southward; though one or two cetacean bones have been found in the corresponding deposits in Suffolk. The Bacton section showed:—

		Feet.
Soil		2
1st Till	Stony loam	4
Upper Freshwater Bed ?	Loamy sand	2
	Sandy loam, bedding obscure	
	Laminated sand and clay	1
Forest-bed (estuarine).	Laminated clay, with a few thin seams of gravel and sand, full of *Mytilus edulis* and *Littorina littorea*	5½

These seams with marine shells were first described by the Rev. C. Green in 1842,* but at that time the exposures appear to have been much more fossiliferous than at present; the cliff has probably now been cut fully 100 yards further back, and the details of the section have quite altered. Green mentions the following species as occurring here:—

Littorina littorea.
Mytilus antiquorum [=M. edulis, Linn].
Scalaria grœnlandica.
——— minuta.
Astarte plana [=A. borealis, Chem.].
Fusus striatus [=Trophon antiquus, Müll.].
——— contrarius [——— ———, reversed var.].
Cardium, fragments.
Turbinolia.

To the above list Prof. Prestwich adds *Littorina rudis* and *Purpura lapillus*.†

The next section of importance is seen near the present Coast Guard Station at Bacton. At this point, and for several hundred yards on each side, the Upper Freshwater Bed again appears immediately under the Till:—

		Feet.
Soil		2
Intermediate Beds.	Laminated marl	1
1st Till	Stony Boulder Clay, with little chalk	7
Upper Freshwater Bed.	Mixed clay and sand, with freshwater shells: *Succinea putris*, *Bythinia tentaculata*, *Cyclas cornea*	2½
	Sand and loam	2½
Forest Bed (estuarine).	Gravel, with thin clay seams	3
	Laminated blue clay	5
	(Strata hidden by beach)	8
	Laminated greenish clay	1

* Geology of Bacton, p. 56.
† *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 465. (1871.)

About a quarter of a mile south-east of Walcot Gap, freshwater clays reappear, apparently forming the north-westerly portion of the deposit which extends to beyond Ostend Gap, filling an eroded hollow in the lower strata. Near the commencement the section was as follows:—

		Feet.
Blown sand		2
Soil		3½
1st Till	Hard stony loam	8
Upper Freshwater Bed.	Hard loam mixed with sand and a little gravel	2
	Hard bedded blue clay, full of *Cyclas cornea*	2
?	(Strata hidden by beach)	6
Forest-bed (estuarine).	Clay-pebbles, coarse red sand, carbonaceous clay, small gravel, and a little lignite and peat	1

The base of the Boulder Clay being here very low, and the beach high, no Pre-glacial beds can be seen, except after severe gales; in fact, one may often walk from Bacton to Eccles without being able to find a trace of any beds older than the Till. A few yards from the spot where the last-mentioned section was measured, Arctic plants (*Salix polaris* and *Betula nana*) were found immediately beneath the Till; so it is possible that the bedded clays may really belong to the higher division and not to the Forest-bed Series. The sections have of late years been too obscure to allow this question to be settled.

At Ostend the Freshwater Bed appears at the foot of the beach, where it was discovered by Green in 1841, but the section is now so altered that the very fossiliferous deposit he found is either entirely swept away or constantly hidden by the beach. There is now to be seen hard thick-bedded freshwater loam, which appears to lie in a hollow excavated in alternating beds of laminated clay and lignite. In this lacustrine deposit no mammalian remains could be found, but teeth and scales of fish, and fruit or seeds of *Trapa natans*, *Ceratophyllum demersum*, *Hippuris vulgaris*, *Pinus sylvestris*, *Pinus abies*, &c. occur. Green obtained an important series of fossils from this place, including bones of deer, mole, shrews, and the Russian desman (*Myogale moschata*).

This freshwater deposit can be traced nearly continuously for a quarter of a mile south-east of Ostend, gradually rising and allowing the underlying beds to be seen. Where good exposures can be examined, roots penetrate the weathered surface of the estuarine beds. South-east of Bacton the middle division of the Forest-bed appears to have become more fluviatile, and consequently it is difficult to separate it from the Upper Freshwater Bed, unless the intervening weathered land-surface happens to be exposed.

About 550 yards south-east of Ostend Gap, at half-tide, there is seen lignite, with seeds of yew, and abundance of fir-cones, resting on loam penetrated by small roots.

For about 100 yards further an important section is only uncovered after exceptionally severe north-westerly gales. Immediately under the base of the Boulder Clay, which lies several feet below high-water mark, greenish sandy clay, in places laminated in the upper part, alternates with beds of lignite full of fir-cones and seeds. At one spot several trunks of fir were observed to lie close together and in the same direction, four of them being upwards of nine feet in length with neither end visible; a few yards away there were two more trunks crossing one another. Unfortunately on account of the water it was impossible to ascertain whether these trunks were overthrown in place or formed a pine raft;—they rested on a carbonaceous sandy and stony clay, probably a continuation of the soil already mentioned. The trunks were of moderate size, originally not exceeding a foot in diameter, but now compressed to about two or three inches; the bark did not appear to be exceptionally thick. Cones of Scotch and spruce fir were abundant, one of the latter having been gnawed by a squirrel. Other seeds were common, including yew, sloe, and probably the yellow water-lily.

Just south of the highest part of the cliff at Happisburgh the base of the Till again rises a few feet above the beach, so that due north of the church another patch of the Freshwater Bed is seen, consisting of lignite with many fir-cones and seeds, resting on hard weathered green stony loam penetrated by roots. At this place there was imbedded the stump of a small tree with the roots penetrating the soil,—the only instance of a tree in its natural position that has been observed. The soil corresponds exactly in character with recent soils of the same neighbourhood, except that is harder. The stones in it are all weathered; the bedding is obliterated, and so are all calcareous fossils, with the exception of a single much-decayed fragment of mammalian bone. Blue concretions of phosphate of iron occur here and at Ostend. The greatest thickness of the Freshwater Bed in this patch does not exceed three feet, and it soon either thins out or entirely changes.

From this point to Happisburgh Gangway we have the usual continual changes and false-bedding of the middle division of the Forest-bed.

It was probably from the two freshwater deposits just described, that the Rev. S. W. King obtained most of the plants determined by Professor Heer;* but as the Post-glacial Alluvium south-east of Happisburgh has till lately been confounded with the Forest-bed, it has been thought safer (in the absence of information as to the exact localities where the specimens were found) to omit from the lists one or two species for which we have no corroborative evidence.

For 200 yards south-east of the Gangway, the Forest-bed is traceable at the base of the cliff, and consists of laminated clay, sand, and clay-pebbles, with drifted wood and tree-stumps. About

* *See* Lyell's Antiquity of Man, 4th ed., p. 256.

350 yards farther, it is seen at the foot of the beach, and can be followed to within a quarter of a mile of the Low Lighthouse; but its lithological character is peculiar, and does not clearly indicate to which division the strata here exposed belong. The deposit consists of carbonaceous silt, full of small pieces of wood, and occasional fir-cones, passing laterally into hard blue-black carbonaceous clay with earthy ferruginous concretions containing scattered twigs.

This is the last exposure of the Forest-bed visible north of Yarmouth, for a few yards further the base of the Boulder Clay sinks below low-water mark. The Forest-bed mentioned by several authors as occurring at Eccles and Palling is undoubtedly a recent deposit, for it can be seen to rest on Boulder Clay.

Though so little of the Forest-bed lies above the sea-level south of Happisburgh, there is evidently a considerable thickness below; for after the storm of January 30th, 1877, large slabs of fresh-water clay-ironstone, and pan were thrown up on the beach at Happisburgh and Eccles. These slabs were full of impressions of leaves of oak, elm, beech, birch, and willow; they contained seeds of the bog-bean, and casts of *Unio pictorum*, *Pisidium*, *Paludina*, *Limnæa*, and a species of fish, probably the roach. Fragments of this fossiliferous ironstone, which appears to represent the Lower Freshwater Bed, occur in the estuarine gravels of the Forest-bed.

As, from the size and angularity of the slabs, the ironstone was evidently in place under the sea at Happisburgh, it was dragged for from a boat during the progress of the Geological Survey. At half-a-mile north-north-east of the Low Lighthouse we found a rocky bottom at 10 fathoms; and as the boat drifted further out the lead swung off what appeared to be a submarine cliff, and dropped into 15½ fathoms, the arming showing sand with black specks in this hollow. We then tried to detach slabs of the rock with grappling irons, but after twice getting them fixed we had to abandon the attempt. The teeth of the irons were bent by the strain, and had evidently played against a fine-grained tough ferruginous rock, like the slabs found on the beach. Six weeks later another attempt was made to examine this ironstone, but where previously there had been a depth of 10 or 15 fathoms, there was now only at most 6½. The presence of sandbanks near the shore causes the tide to flow in regular channels, which, during gales, are scoured to a great depth, only to be again filled up. In this way submarine denudation perhaps proceeds at depths considerably greater than in the open sea.

There is no evidence as to the full thickness of the Forest-bed at Happisburgh, but it seems to extend from high-water to at least 10 fathoms below low-water (including the ironstone), which would make it over 70 feet. From the occurrence of the submarine cliff mentioned above, it is clear that the ironstone rests not on Chalk but on soft beds, which descend to at least

15½ fathoms. These beds may be Eocene, but if belonging to Crag, they raise the total thickness of the Pliocene Beds at this point to over 100 feet.

About three-quarters of a mile from the shore, opposite Happisburgh, large quantities of bones and teeth of elephant, &c. have been obtained by the oyster dredgers. The oysters are now all destroyed, and dredging is stopped, but fossils were already getting scarce. The Rev. J. Layton, who was living at Catfield when the oyster-bank was discovered, made a large collection of the fossil bones.* Samuel Woodward, writing in 1833, observes that "The oyster-bed off Hasbro' was discovered in the year 1820, and during the first 12 months many hundred specimens of the molar teeth of the elephant were destroyed by the fishermen, who amused themselves by breaking them, their wonder being excited by the grinders separating into laminæ."† The Forest-bed specimens dredged from the Happisburgh oyster-ground must not be confounded with the Pleistocene mammalia obtained abundantly by trawlers on the Dogger Bank. As the Yarmouth trawlers pass Happisburgh on the way to the Bank, and also trawl in that neighbourhood, some of the dredged fossils in collections have probably been put down to the wrong locality.‡

From Happisburgh to Hopton, north of Lowestoft, there is a stretch of 22 miles of low coast, along which no Pliocene strata are visible; but where the Forest-bed reappears its lithological character is scarcely altered. Near Hopton, about 440 yards south of League Hole and under the highest part of the outlier of Chalky Boulder Clay, Mr. Blake has observed the first section of the Forest-bed, and from this point to Corton Gap the deposits have been followed almost continuously.

In the cliffs near Corton it is doubtful to what extent the threefold division of the Forest-bed series recognised near Cromer will hold good, for both above and below the land surface there are found lacustrine and fluviatile deposits, without, as far as is yet known, any trace of marine or estuarine fossils, except a single cetacean vertebra. The following description of the strata is taken from the notes and section§ made by Mr. Blake; supplemented by trial-borings put down in 1886; and notes made during the visit of the members of the International Geological Congress in 1888.‖

Pliocene strata can be traced in Corton cliffs for about three-quarters of a mile. The upper portion—only preserved where the base of the Lower Boulder Clay rises a considerable height above the beach—consists of pebbly quartzose sand, with laminated grey and brown clay. No fossils have yet been observed

* Layton, Account of the Fossil Remains in the Neighbourhood of Hasborough, *Edin. Journ. of Sci.*, vol. vi., p. 199. (1827).

† S. Woodward, Geology of Norfolk, p. 23.

‡ *See* papers by W. Davies, *Geol. Mag.*, vol. v., pp. 97, 443. (1868.)

§ Horizontal Sections, Sheet 128. (*Geological Survey.*)

‖ *Trans. Norf. Nat. Soc.*, vol. iv. p. 606. (1889.)

in these strata, and it is still somewhat uncertain to which horizon they may belong. They may form part of the Forest-bed series, or of the *Leda-myalis* Bed, or may be considerably newer.

Beneath these pebbly sands there is sometimes a thin layer of much compressed lignite, resting directly on the old land-surface or "Rootlet-bed," and apparently intimately connected with it. Then comes the Rootlet-bed, which "consists of a greenish and dark bluish-grey unstratified clay, with occasional white calcareous concretions ("race") and ferruginous sandy concretions, and it contains mammalian remains . . . Thousands of rootlets may be seen here, at times, penetrating the bed vertically as they grew . . . . . They vary from about $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch in thickness at the surface and gradually taper away to nothing, as at Kessingland and Pakefield; all are more or less crumpled, similar in appearance, and only occasionally forked."* The roots are similar to those of pine, but those which I examined were not sufficiently well preserved definitely to show coniferous structure under the microscope, and all we can say is that they belong to some exogenous tree.

The strata below the Rootlet-bed are very seldom exposed, but in one spot Mr. Blake observed about three feet of stratified grey and brown clay and brown sand, and in three of the borings made by the Geological Survey gravels with quartzite pebbles were met with—as was the case near Happisburgh. The gravel was so loose and full of water that none of the borings at Corton could be carried to its base; the thickness of the Forest-bed series, and the nature of the underlying deposits are therefore still unknown.

At the point where the Pliocene strata first rise above the beach, and for 200 yards further south, the clayey Rootlet-bed is immediately overlain by Boulder Clay. This absence of any pervious beds has led to the preservation of calcareous fossils, so that here, and here only on this part of the coast, are mollusca found in the Rootlet-bed. By far the commonest species is *Helix hispida*, but Mr. Blake also records *Bythinia tentaculata*, *Limnœa stagnalis*, *Planorbis corneus*, *P. spirorbis*, *Succinea putris*, *Valvata piscinalis*, and a *Unio* or *Anodon*. Mammalian bones also occur in the deposit.

A trial-boring further south, about midway between the two outliers of Chalky Boulder Clay, was interesting as showing the character of the Rootlet-bed at a spot where all shells have disappeared. This boring also proved the nature of the underlying deposit, which there is little doubt should also be referred to the Forest-bed series:—

		Feet.
Forest-bed Series.	Peaty layer with lignite	$\frac{1}{4}$
	Unctuous blue-grey clay (Rootlet-bed)	$3\frac{3}{4}$
	Whitish hard marl or clay, with a few small stones	$\frac{1}{2}$
	Ferruginous gravel with quartz and quartzite	$3\frac{1}{2}$

* J. H. Blake, Geology of Yarmouth and Lowestoft. (*Memoirs of the Geological Survey*), p. 20.

A short distance further south, and not far from the road to Corton Church, a block of the Rootlet-bed and of the overlying peaty seam, was taken by me for minute examination, from one of a series of sections which, through the liberality of Mr. Colman, had been opened up for the inspection of the members of the International Geological Congress.*

The thin bed of lignite seemed so distinct from the underlying clay, that it was carefully detached and treated separately. When washed and examined, the residue proved, however, to be nothing but a deposit of twigs, seeds, and miscellaneous floating scraps, such as marks the high-water level of a flood at the present day. The most common seeds were those of Alder and Hornweed; but as all the species occur still more abundantly in the bed below, it is unnecessary to give a separate list.

The underlying carbonaceous clay is snuff-coloured when dry, and splits readily into thin laminæ, but does not fall to pieces in water. The surface of the flakes was carefully examined for leaves, with the result that portions of the stem and leafy bracts of the cotton grass were found plentifully; but there was nothing else, except a single fragment of a dicotyledonous leaf, probably already skeletonised when it was imbedded. Scales of two or three species of fish were also noticed. The next process was to boil down the fragments of clay till the matrix could be washed away, leaving only twigs and seeds, for not a single stone was met with.

Unlike most of the deposits near Cromer which I have examined for seeds, the Corton beds seem to have been deposited as flood-loam, and not as true lacustrine clays. Aquatic plants are comparatively scarce, the common species being such as we should find on an alder swamp, or "carr" as it is called in the east of England. The alder itself is abundantly represented by cones and seeds; other trees are only recognisable in the driftwood. Cotton grass and a species of buttercup come next in abundance. Then follow the hornweed, several sedges, pond-weeds, bur-reed and *Atrpilex*.

The seeds are much compressed, more so than is usually the case near Cromer. But this, and the greater amount of decay they have undergone, may be the result of longer exposure to the weather in pre-glacial times. A seed sinking at once to the bottom of a lake suffers less than one exposed for a time to alternate flood and drought. It is also probable that many of the seeds from Corton had germinated, but their state of preservation is not such as to allow this question to be decided.

About a hundred yards south of the road to the Church, the Lower Boulder Clay descends, cutting through the pebbly sand, and resting directly on the Rootlet-bed, as was the case near Hopton. A few yards further, its base sinks still lower, so that no Pliocene beds can be seen in the cliff, though a boring immediately north of Corton Gap showed that there the Boulder Clay

* See *Trans. Norf. Nat. Soc.*, vol. iv., p. 606. (1889.)

has cut out the Rootlet-bed also, and rests on the gravels. The section obtained in this boring, which commenced about three feet above high-water level, and two feet below the top of the Boulder Clay was :—

		Feet.
Lower Boulder Clay.	Brown loam with fragments of shells	4½
	Blue clay and white specks (of flint?)	1
	Brown sandy loam	1½
Forest-bed Series.	Gravelly quartz sand and gravel, full of water	4½

Then the Pliocene strata are lost for about four miles and do not reappear till we have passed Pakefield.

The first section seen at Pakefield is exactly opposite the end of the Grand Avenue, where six inches of gravelly pan were seen on the foreshore, at the level of high-water. Beneath this lie laminated clays and sand to the depth of twelve feet, as proved by boring. The pan may be either the base of the Forest-bed, or may belong to the higher "pebbly beds," which directly overlie the Chillesford Clay in the cliffs a short distance further south. Fossiliferous strata undoubtedly belonging to the Forest-bed series do not appear till we have passed Pakefield Lighthouse Gap, though both the Chillesford Clay and the pebbly gravels can be traced continuously for three and a half miles north of that point.

About fifty yards south of the Lighthouse Gap an eroded hollow in the Chillesford Clay (shown in Mr. Blake's section*) is occupied by loam, sand, and gravel full of quartz and quartzite pebbles. This deposit, which extends for about 430 yards, Mr. Blake refers to the Lower Boulder Clay; but from its position, the composition of the gravels, and the absence of Boulder Clay stones, I think it is more probably a weathered representative of a portion of the Forest-bed like that next to be described.

At two hundred yards south of the Gap another eroded hollow commences, and the deposits filling it seem undoubtedly to belong to the Forest-bed series, for they contain throughout the characteristic fossils. This hollow extends nearly as far as Kessingland, and the reading which most simply explains the variation in the deposits filling it, is that here we find another of the eroded channels so characteristic of the Forest-bed. As the channel became disused and silted up there were deposited, first the river gravels and alluvial clays with drifted bones; and then, only in the last part of the channel to be occupied, peaty mud full of leaves, twigs, and seeds, such as would settle in any stagnant backwater. Thus for over half-a-mile south of the parish boundary only gravelly deposits occur, capped by alluvial clay, which is weathered in its upper part and penetrated by roots. At the northern side of the valley the remains of the last trench occupied by the river may be observed. This was bounded on its southern side by an old alluvial flat, covered by

* Horizontal Sections, Sheet 128. (*Geological Survey.*)

trees of which portions of the roots remain; but to the north the river was cutting into a bank of Chillesford Clay. Thus the bank is much steeper on that side, and there is no Rootlet-bed there.

The relation of these deposits to the Chillesford Clay, is, however, disputed. Mr. Blake considers that the laminated clays immediately above the gravel pass laterally into the Chillesford Clay; thus making the gravel, with its Forest-bed fauna, older than the Chillesford Clay, and equivalent to the Norwich Crag.* This view is difficult to accept, for in 1886, with an exceptionally clear exposure of the northern end of the hollow, a thin seam of pebbles was traced, cutting obliquely across the Chillesford Clay, and separating the two somewhat similar deposits. Then by boring it was found that the channel was somewhat deeper than had been thought, and cuts entirely through the Chillesford Clay. Thus in places the mammaliferous gravel seems to rest immediately on shelly Crag.

As the sections at Pakefield and Kessingland are fully described in Mr. Blake's Memoir, it will only be necessary here to allude to some of the more interesting points. The conspicuous channel filled with black peaty loam yields few or no mammals, the only trace of vertebrates commonly found being fish-scales. For plants this is one of the best localities. The first sample washed and examined, in 1885, was a lump of material weighing about five pounds. This was obtained near the base of the deposit, on the northern side of the channel. It was full of decayed oak-leaves, and yielded 25 species of seeds and fruits. Since that time Messrs. R. E. Leach and T. P. Angell have sent me all the specimens obtained by them in the same deposit, with the result that the list now contains about 37 species. Of these 8 are forest-trees. The rest are all aquatic or marsh plants, with the exception of a single winged seed of a Composite, and a woodland Spurge. The only species yet determined which is not living in the neighbouring parts of Norfolk at the present day, is the Water Chestnut. There are two or three peculiar fruits which seem also to be locally extinct, but these so far have not been identified. They, however, like the *Trapa natans*, are characteristic of the Forest-bed, and help to prove the accuracy of the correlation of the different isolated exposures. The forest trees are particularly important, for they include three that do not now range much north of Norfolk. These are the Lesser Maple, the Cornel, and the Hornbeam. The Pine and Spruce are missing at this locality.

Below the southern margin of this hollow, and underlying the Rootlet-bed also, there is ferruginous gravel containing *Unio* with

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* *See* Presid. Address On the Age and Relation of the so-called "Forest-bed" of the Norfolk and Suffolk Coast.—*Proc. Norwich Geol. Soc.*, pp. 137–160. (1881.) *Also* Horizontal Sections, Sheet 128, and Explanation, 8vo. (*Geological Survey*); and Geology of the Country near Yarmouth and Lowestoft. (*Memoirs of the Geological Survey.*)

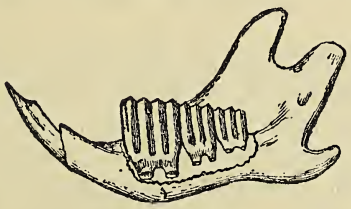
the valves united—as in the "Unio-bed" at Sidestrand. This gravel is seldom laid bare, as it lies beneath the beach level. Ninety yards south of this point, shelly Crag directly underlies the mammaliferous clays of the Rootlet-bed, rising apparently to about half-tide level. Eighty yards further, carbonaceous gravel again descends to low-water and has here yielded a good many bones.

For some distance south the section calls for no remark, the Rootlet-bed being of the ordinary character, and containing scattered bones throughout. About a quarter of a mile north of the old Coast Guard Station, six to twelve inches of peat with seeds overlie the Rootlet-bed. Then the Forest-bed soon rises and tends to thin out, so that the Chillesford Clay reappears above the beach. About 80 yards from the flagstaff at Kessingland Mr. Blake found a hollow full of black silt, occupying the lower-part of the Rootlet-bed. From it he obtained wood, seeds, fish-bones, scales of Perch, and bones and teeth of the characteristic Upper Pliocene vole, *Arvicola intermedius*. (Fig. 42.)

Fig. 42.

Arvicola intermedius, Newt. (*lower jaw, broken to show the fanged teeth*).

Twice natural size.



This is the most southerly point at which the Forest-bed has yielded fossils. The weathered soil can be traced as far as the end of the cliff; though this part of the section is usually obscured by sand dunes, and has not produced fossils.

Where the cliffs recommence, at Covehithe, the Forest-bed has disappeared, and pebbly sands rest directly on the Chillesford Clay. There may possibly be a trace of the old land-surface, for the upper part of the clay is penetrated by roots. These, however, are considered by Mr. Whitaker to belong to recent plants. The only other deposit that is at all likely to represent the Forest-bed, is the clay with lignite, above the Crag in the cliff at Walton Naze (see p. 83). This deposit is usually referred to the Chillesford Clay, and in the absence of fossils nothing more can be said about it.

On attempting to compare the fossils of the Cromer Forest-bed with those of the underlying Crag, we meet with considerable difficulty. In the one case we are dealing mainly with a land fauna and flora; in the other, with little but marine mollusca. This has often led geologists to think that a considerable break

occurs between these divisions, for at first sight the species living during the two periods seem to have been quite different. They also point to somewhat different climatic conditions. The Forest-bed has sometimes, for this reason, been separated from the rest of the Pliocene strata, and has been called Older Pleistocene. It, however, yields a very different fauna from that of the true Pleistocene deposits with which it is thus correlated.

When examined more closely, and with the advantage of the greater amount of positive evidence now available, the Norwich Crag and the Forest-bed are found to be intimately allied. They are so closely connected, that they can only be separated as slightly different horizons in the same period. The real break, if a line must be drawn, is above the Forest-bed not below it.

Let us examine first the marine mollusca—always taken as the test to decide questions of this sort. These, unfortunately, are very poorly represented in the Forest-bed. There are only 19 species yet known; of which several may be derived from the Weybourn Crag. They are all common Weybourn Crag shells, and include several extinct forms, such as *Melampus pyramidalis, Tellina obliqua*, and *Nucula Cobboldiæ*. As far as they go, they tend to show that there has been no change in the molluscan fauna. There are several arctic species among them; indicating that the temperature of the sea was also little altered.

The other marine fossils of the Forest-bed are the Cetacea and the Seals. These also point to boreal conditions; but so little is yet known of the species belonging to the Weybourn Crag and to the Chillesford Clay, that no comparison is possible. Mr. Newton has now determined nine species from the Forest-bed. Of these one—a walrus (*Trichechus Huxleyi*)—is a characteristic Crag form; the others are still living. The next Cetacean fauna below the Forest-bed lies at the base of the Red Crag, in the Nodule Bed.

Among the few marine fish yet known from the Forest-bed the characteristic Upper Pliocene *Platax Woodwardi* is the most abundant. It is more plentiful on this horizon than anywhere else. The tunny (*Thynnus thynnus*), recently discovered in the Forest-bed, is a fish belonging to warmer seas than ours. Probably the single vertebra found belonged to a stray individual, like those that visit our coast at short intervals, and stray even as far north as Shetland. This completes the marine fauna of the Forest-bed. It is evident that a close connexion exists between this horizon and the Weybourn Crag; but until we have considerably larger lists of fossils, it will be impossible to say whether the deposits are nearly continuous, or whether there is a slight gap between.

Turning next to the inhabitants of the land, and of the lakes and rivers, we find plenty of material for an analysis of the Forest-bed fauna and flora, but little for comparison with the older strata. Freshwater strata are unknown in the rest of our

Pliocene series, and land and freshwater animals only occur as accidental introductions.

Among the large mammals the most abundant and conspicuous are the elephants, of which the Forest-bed contains three species. Those commonly met with are *Elephas meridionalis* (Fig. 43) and *E. antiquus*, though several teeth have now been found

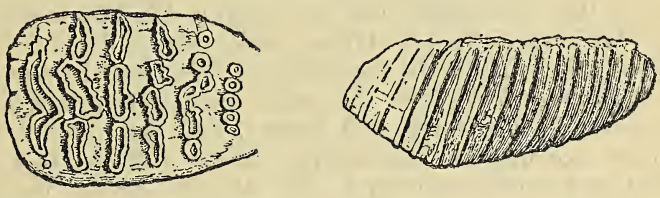
Fig. 43.

Elephas meridionalis, Nesti (*upper molar, from a specimen found at Dewlish*).

(See *Quart. Journ. Geol. Soc.*, vol. xliv., p. 823.)

Grinding surface. ¼ natural size.

Side view. ⅛ natural size.



of a very distinct form, perhaps referable to *E. primigenius*. The *Mastodon*, the common proboscidian in the Norwich Crag and strata below, has entirely disappeared, not a single specimen having yet occurred among the many hundred teeth of elephant which have been obtained from the Forest-bed. Hippopotamus and *Rhinoceros etruscus* are fairly abundant, and there seems also to be a second species of rhinoceros. Two horses, one of which is extinct (Fig. 46), the bison and boar, an extinct species of mouflon (*Caprovis Savinii*), and deer in seemingly endless variety complete the list of the ungulata. The carnivora are imperfectly known, they include two bears, *Machærodus*, the spotted hyæna, wolf, fox, glutton, otter, and marten. Of rodents there is the beaver, and an extinct ally, the *Trogontherium*. There are also several voles and a field mouse. The presence of the squirrel seems to be indicated by gnawed fir-cones. The insectivora are represented by the mole, two shrews, and the Russian desman (*Myogale moschata*). The associated birds, reptiles, amphibia, and freshwater fishes are, as far as is yet known, all living British species.

Fig. 44.

Equus Stenonis, Cocchi.

Half natural size.

Mr. E. T. Newton has drawn up the following table for the comparison of the land mammals of the Forest-bed with those

of the older and newer deposits; but any definite conclusions are at present rendered somewhat unsafe, through the deficiency of our knowledge of the contemporaneous mammals of the various parts of the Crag.

Distribution of the Land Mammals.

	Total Species.	Living.	Extinct.
Nodule Bed - - - -	28	3	25
Norwich Crag - - - -	13	1(?)	12
Forest-bed - - - -	45	24	21
*Pleistocene - - - -	49	41	8
Living British (exclusive of Bats) -	29	29	—

At first it does not seem clear why the Glacial Epoch should have exterminated so many large mammals and left the smaller species; but a more minute examination of the fauna shows that most of the forms which did not survive till Pleistocene times were highly specialized herbivora which would die out through the gradual change in the vegetation as the climate became colder. The surviving forms, on the other hand, are principally the omnivorous voles, mice, and shrews, and the carnivora. All these can accommodate themselves without difficulty to a change of diet, and would probably be able to exist through the Glacial Epoch north of the Alps, or at least to pass that barrier, and return when the climate ameliorated.

The occurrence of the glutton, now an exclusively northern species, might be thought to imply greater cold during the formation of the Forest-bed than is now felt in Norfolk; but the great climatic range of many living carnivora, which seem limited more by want of food, competition, or human agency than by temperature, renders the occurrence of a species now confined to northern latitudes of very little value in evidence, when counterbalanced by the numerous ungulata. One ungulate only, the musk ox, has at the present day an exclusively northern habitat.

In analyzing the mammalian fauna of the Forest-bed, the first thing that strikes one is the marked contrast, long since pointed out by Lyell, between the familiar character of the plants, most of which are now living in Norfolk, and the strange appearance of the mammals. We can point to no part of the world where a similar assemblage is now living; for though South Africa shows an equally varied fauna of large species, the deer of the Forest-bed (Figs. 45, 46) are there replaced by antelopes. Of 30 large land mammals found in the Forest-bed, only three are now living in Britain, or have been living there within the historic period, and only six still exist in any part of the world. The small inconspicuous mammals, which are also the lowest

* On the authority of Prof. Boyd Dawkins, *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 395. (1880.)

types, are mostly recent forms; but as the smaller species are almost unknown from the strata beneath the Forest-bed, any

Fig. 45.

Cervus verticornis, Dawk.

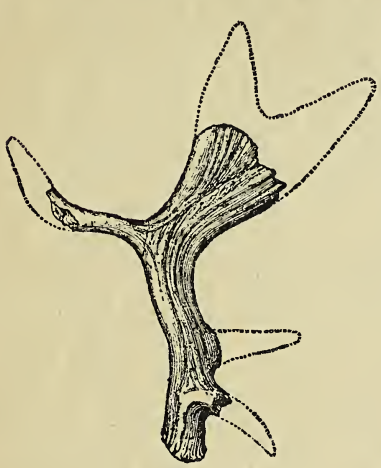
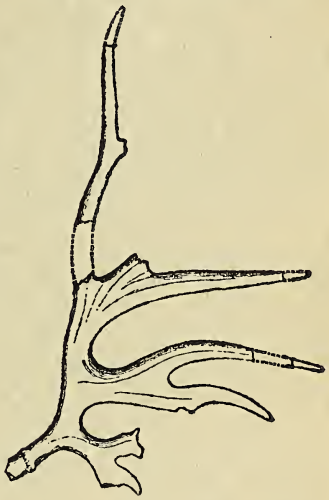


Fig. 46.

Cervus Sedgwickii, Falc.



comparison between the deposits must deal exclusively with the larger species. The large mammals are fairly well known from each horizon.

The land and freshwater mollusca of the Forest-bed number 58 species. Five of these are extinct, and five others do not now live in Britain.* (*See* Pl. V.) The proportion of extinct forms is nearly identical with that found among the marine mollusca of the Weybourn Crag. It is commonly stated that the rate of change is much slower among the freshwater mollusca than among the marine forms. There is, however, no indication of this slowness in the Forest-bed, or in any other Tertiary deposit that I have examined. What we generally find is that among the freshwater mollusca a few large genera have a wide range in time, but their specific forms vary as quickly as among the marine mollusca. Among the freshwater species two or three help to connect the Forest-bed with the Pliocene strata of the continent. Thus we find a slug, *Limax modioliformis*, closely allied to a species from the Val d'Arno (*Sansania Bourguignati*, De Stefani), perhaps identical with it. *Nematura runtoniana* is also more like certain forms from the Val d'Arno than to anything else. The continental species have all a southern range.

In the Weybourn Crag only 10 species of land and freshwater mollusca have been found. Of these two are extinct and two

* If we accept Prof. Sandberger's determinations there are several more extinct forms in the Forest-bed, and the proportion is much greater than among the marine mollusca.

others no longer inhabit Britain. This is too small a number for comparison, but it is noticeable that with one exception all the species occur also in the Forest-bed. The one exception is *Lithoglyphus fuscus*, a river shell now confined to the Danube, and unknown recent or fossil in Northern Europe, except at one locality in the Weybourn Crag, and one near Berlin.

The Norwich Crag has yielded 26 species of land and freshwater shells. All of these, with the exception of two recent forms of *Limnæa* and one of *Pupa*, are also found in the Forest-bed. There are only two extinct species in the list, and one other locally extinct. It is thus evident that, in the present state of our knowledge, the proportion of extinct land and freshwater mollusca is identical with that found in the Forest-bed.

In the upper Red Crag the land and freshwater molluscan fauna still remains the same as in the higher strata. Of 17 species known, two are extinct, and three have disappeared from Britain. Two of the latter are, according to Wood, arctic species of *Limnæa*,* the other is *Corbicula fluminalis*. The Walton Crag seems to indicate a complete change in the climatic conditions, for of the 4 species of *Helix* known (there are no freshwater shells) three are southern and the other is extinct. It therefore appears that we have one set of land and freshwater mollusca ranging throughout the upper Crag and Forest-bed of Norfolk, and that the proportion of extict forms is about the same in each division.

It is instructive to compare the entire fauna of the Forest-bed with the recent fauna of Britain, classed according to the conditions under which the species live. This mode of analysis brings out the fact that while of the Forest-bed aquatic and marsh-loving forms we have a fair knowledge, of the others, except the land-mammals of the plains, at present very little is known. For this purpose the following table, which includes only the more important classes, has been drawn up. In the first column the approximate number of existing British forms, with the addition of a few mammals exterminated within the historic period, is shown; in the second is given the total number of species known from the Forest-bed:—

	British.	Forest-bed.
Bats	14	0
Land mammals	29	40
Amphibious mammals (freshwater)	4	6
Marine mammals	28	11
Birds	354	7
Reptiles	5	2
Amphibia	7	4
Freshwater fish	52	10
Marine fish	210	6
Land shells	77	17
Freshwater shells	48	41
Marine shells	465	19

* Both somewhat doubtful determinations.

The land shells of the Forest-bed are exclusively those found on alluvium or in wet moss. There is not a single representative of the numerous species confined to dry or calcareous soils.

Plants in the British Pliocene deposits are only known from the Cromer Forest-bed. As there is also no other Upper Pliocene flora of any extent yet discovered in Northern Europe, it is impossible to compare the floras of the different horizons. From the Forest-bed 56 species of flowering plants have now been determined. Two of them—the water chestnut and the spruce fir—do not appear to have belonged to our flora since the Glacial Epoch; the others are nearly all still living in Norfolk. There is also a considerable number of seeds still undetermined, and at least two of these seem to belong to no living British plant.

As evidence of the climatic conditions which prevailed during this period, the first place must be given to the flora. The slow rate of change, which renders plants so untrustworthy in settling questions of geological classification, gives them the highest value when we inquire into former climatic conditions. Plants are also, as a general rule, more directly affected than animals by changes of temperature and rainfall.

The flora contained in the Cromer Forest-bed may be divided into two groups: the forest-trees, and the marsh and aquatic plants. Of the upland plants, and of the plants of dry or chalky soils we at present know absolutely nothing. The forest-trees are well represented—in fact they are better known than in any of our later deposits. We find the maple, sloe, hawthorn, cornel, elm, birch, alder, hornbeam, hazel, oak, beech, willow, yew, pine, and spruce. This is an assemblage that could not well be found under conditions differing greatly from those now existing in Norfolk. There is an absence of both Arctic and South European plants. The variety of trees shows that the climate was mild and moist. The occurrence of the maple and hornbeam show that it can have been little, if at all, colder than now. The aquatic plants point to the same conclusion, though not so definitely, as the majority of them are widely dispersed.

Both the fauna and flora, leaving out the large mammals and other extinct forms, are curiously similar to those of the "Broad District" of Norfolk at the present day; and this, like the rest of the evidence, points to a wide alluvial plain with lakes and sluggish streams, bounded on the west by a slightly higher sandy country covered with fir-forests and distant from any hills. A careful examination of the deposits now forming, and of the natural history of the neighbouring country, will, more than anything else, assist in the study of these Newer Pliocene strata; for, notwithstanding the great changes which have taken place since the Forest-bed was formed, conditions almost exactly similar to those which held during the deposition of the Upper Freshwater Bed, reappear at the present day in the Broad District.

The large number of mammals already known from the Forest-bed, seems clearly to point to a connection with the continent and to wide plains over which the animals could roam. We can hardly suppose that had Britain then been an island, it could have supported so large a fauna, including about 15 species of deer, three of elephant, and numerous other large forms. At present our acquaintance is principally with the aquatic mammals, or with those which inhabited the open plains, the Newer Pliocene upland and sylvan forms being still imperfectly known. A study of the lists of fossils shows, therefore, that we may expect to discover in the Cromer Forest-bed not merely a fauna and flora equal to that now living in this country, but one as varied in character as that of central Europe, with the addition of numerous large mammals which, since the close of the Pliocene period, have been exterminated by the cold of the Glacial period or by human agency.

The freshwater mollusca point even more decidedly than the mammals to continental conditions. There are only 48 species now living in the whole of Britain; but we have already discovered 41 in the Forest-bed within a very limited area. Taking into account the absence in these lacustrine deposits of many of the species needing swiftly running water, it seems safe to conclude that only about two thirds of the species then inhabiting Britain have yet been discovered. This would make the molluscan fauna much larger than it is at present, but the occurrence of a considerable number of exotic forms in the Forest-bed shows that it may well have been so.

In the last chapter attention was drawn to the very arctic character of the marine fauna of the Weybourn Crag; a character which, as the late S. V. Wood so ably showed with regard to the mollusca, became steadily more and more prominent during the whole of the Pliocene Period, from the Coralline Crag upwards, through the gradual dying out of the southern forms, and multiplication of the northern. But when we turn to the land and freshwater mollusca the result does not correspond; for of the 59 species now determined from the Forest-bed, 48 are at present living in Norfolk, 6 are extinct,* 2 are continental forms living in the same latitudes as Norfolk (*Hydrobia Steinii*, Sweden and near Berlin, and *Valvata fluviatilis*, Belgium and Germany); and the other 3 are all southern forms not now living in northern Europe (*Hydrobia marginata*, South of France, *Lithoglyphus fuscus*, Danube, and *Corbicula fluminalis*, Nile). There is not a single species having an especially northern range. It may be objected that the Forest-bed fauna and that of the Weybourn Crag are not exactly contemporaneous,

* Dr. Sandberger has described six other species as new. These have not been included, as they are evidently varieties of living forms. The figures given by Dr. Sandberger are not accurate, but good specimens of all the forms will be found in the Museum of Practical Geology. *See Palæontographica*, Band vii., p. 83. (1880.)

and that a change of climate may account for the discrepancy. But, in reply to this, it is enough to point out that the most typically southern of the freshwater mollusca occur mixed with the arctic marine shells in the Weybourn Crag, and that several of the arctic marine species occur in the Forest-bed. We may therefore fairly conclude that the two faunas lived in adjoining districts during the same period. I have laid special stress on the comparison of the mollusca, for we have long lists of the species inhabiting the land, the sea, and the lakes; nevertheless, as far as known, the same discordance affects other classes. The land mammals have a decidedly southern facies, while the marine forms seem distinctly northern. The plants of the Forest-bed are not arctic. To explain these contradictions, it will be necessary to bring forward more evidence as to the conditions under which the animals and plants flourished. The changes in physical geography since the Pliocene period have a very direct bearing on the question.

The most important feature in the physical geography of the period was undoubtedly the large Forest-bed river. If the direction of the flow of the river can be traced, we have the key by which the general topography of the country can be made out. With a view to decide this question, the old river gravels have been carefully examined, for they must have been derived from the land over which the river flowed. These gravels commonly contain fully 40 per cent. of stones other than flint; and after a study of the Glacial gravels and Boulder Clay stones, it is at once clear that they must have come from quite different districts. The proportions of the different rocks in 500 stones over an inch in diameter obtained at Bacton was:—

Little worn flints	141
Pebbles of light-coloured fine-grained quartzite	125
„ flint	101
„ vein quartz	54
Pebbles of hard sandstone	6
„ fine-grained grit	5
Angular Greensand chert	4
„ green or bluish slaty rock	3
Clay-ironstone (very variable)	61

Various other rocks have been obtained in smaller numbers; and in the following list an attempt has been made to show the probable age of the deposits from which the whole have been derived:—

Clay-ironstone with plant remains. Cakes of peat, often bored by *Pholas*	Lower Freshwater Bed.
Jet, amber, and brown coal	Upper Eocene?
Green-coated flints (common) Hertfordshire pudding-stone Silicified wood	Lower Eocene.

Unworn Chalk flints	Upper Chalk.
Greenish chert	Greensand or Neocomian.
Cherty sandstone with fossils	
Rubbly limestone with *Pecten demissus*	Oolite.
Well-worn pebbles of white or cream-coloured fine-grained quartzite, vein-quartz, black or purple grit, hard coarse sandstone, &c.	Pebble-beds of unknown age.
Angular fragments of a fine-grained green or bluish slaty rock	Carboniferous.
Carboniferous Limestone chert	
Fragments of *Hyalonema*	
Felstone.	
Granite.	

In these Pre-glacial beds few igneous rocks occur. With the exception of the single large granite boulder already mentioned and one of felstone, none were met with. The liver-coloured quartzites so characteristic of the Triassic conglomerates in the Midland Counties are also missing; so that, even if the pebble-bed is of Triassic or Permian age, it cannot have been derived from those rocks in the Midland Counties. In fact, if the river had flowed from the south, west, or north, it must have brought a quite different collection of stones. From the north-east it would probably flow entirely over Chalk. It therefore seems that only from the south-east and east could the stones be derived. The evidence appears to point to a river flowing (tracing it towards its source) first over the Lower Tertiary basin which we know exists east of Yarmouth, then over Chalk, Greensand, and Oolite, and a conglomerate perhaps of Cretaceous or Neocomian age, which may have overlapped against the Palæozoic rocks, as beds of that age are known to do near Harwich. The Palæozoic rocks probably came to the surface as part of the old ridge which Mr. Godwin-Austen has described. From them the angular pieces of slate and carboniferous-limestone chert may have been derived.

That the river must have been large is shown by the uniformity of the composition of the gravels at considerable distances apart; the gravel of a small stream will generally be of local origin. From the size and angularity of many of the stones it is evident that they must have been brought down by river-ice. This would not necessarily point to a more arctic climate than that of Norfolk at the present day, for during severe winters the ice-floes on the Thames are quite capable of transporting the largest of the boulders. Prof. Prestwich remarks* that on the table-land above the Meuse, in Belgium,

* *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 477. (1871.)

there is a gravel of a very similar character, and suggests that the stones may have been brought to Norfolk by some old river traversing the Ardennes. The plateau gravels above the Meuse are, however, full of veined quartzites of a character unknown in the Forest-bed. The Forest-bed river appears certainly to have flowed from that direction; but it seems unnecessary to bring the materials such a long distance, though a large stream with floating ice could probably do so. The whole of the evidence seems to show that in the Forest-bed we are dealing with the old alluvial and estuarine deposits of the Rhine—a view held by various writers ever since the Forest-bed was first known.

The changes that took place during the Newer Pliocene period may be thus summarized. During the formation of the Coralline Crag there was a considerable submergence of the land, and free connexion between the German Ocean and more southern seas. Afterwards the land rose, and the connexion with all seas, except the Arctic, was cut off.* A further rise caused the estuarine and freshwater Forest-bed to spread over the southern half of the North Sea.

If the marine fauna of the different Crags is examined, a gradual dying out of southern forms and increase of northern may be perceived, till at last in the Chillesford and Weybourn Crags the mollusca have a thoroughly arctic facies. This change has generally been referred to the greater intensity of the cold; but in working out the physical geography of the Pliocene Period, I have been led to agree with Prof. Prestwich, that it is not altogether due to general climatic changes. When the connexion with southern seas was cut off, the direct cooling action of northern currents, without any from the south, must have had a considerable effect on the temperature of the water.† But probably the change in the fauna was principally due to the sea being fully open to the north, so that there was a constant supply of arctic species brought by every tide or storm, while at the same time the southern forms had to hold their own without any aid from without; and if one was exterminated, it could not be replaced. In this way, of two species, a southern and a northern, equally fitted for any station, the northern would have the best chance of surviving, and would probably exterminate the southern. The fact that not a single southern species appears for the first time in the Fluvio-marine, Chillesford, or Weybourn Crags seems clearly to show that they could not migrate into the district, owing to some barrier.

Taking now the land fauna and flora, it is seen that the same elevation which would raise a barrier to the migration of marine species, would form a highway for the land and freshwater forms,

* *See* Godwin-Austen On the Kainozoic Formations of Belgium, *Quart. Journ. Geol. Soc.*, vol. xxii., p. 238, 1866; and Prestwich On the Structure of the Crag Beds, *ibid.*, vol. xxvii., p. 475 (1871).

† *See* Prestwich, *op. cit.*, p. 478.

and we can apply to these the same reasoning as is used above, merely changing *north* for *south*. The southern species would be able, under these circumstances, to spread down the valley of the Rhine in a continuous stream. Their march would not be checked by the previous occupation of the country by arctic forms, for there does not appear to have been any land-connexion between Britain and Scandinavia till a later period. The southern fauna could thus occupy the whole of those portions of Britain where the climate was suitable. The local extermination of any species by an exceptionally severe winter would be of little consequence, for it could be immediately replaced by other individuals, and there were no boreal forms to take possession of its district.

Thus it is that in the Forest-bed we find a distinctly southern land fauna contemporaneous with an equally marked arctic marine fauna; the plants at the same time showing that the climate was much the same as that of Norfolk at the present day, though perhaps more continental, *i.e.*, hotter in summer and colder in winter.

CHAPTER X.

DEPOSITS OF DOUBTFUL AGE.

In the previous Chapters most of the British Pliocene strata have been described. There remain, however, a number of deposits which undoubtedly belong to some part of the series, but have not yet yielded evidence sufficient to fix their exact horizon. There are other strata of more doubtful age, though probably pre-glacial. We have also still to trace the connection between the Pliocene beds and the overlying glacial deposits. Owing to the uncertain age of so many of the outliers, the only classification that can be adopted in the present Chapter is a geographical one. We will commence, as a matter of convenience, with the area in which the series appears to be most complete.

In the last Chapter the Cromer Forest-bed, with its prolific fauna and flora, was described. It was shown that this deposit clearly belongs to the Pliocene period; though perhaps to a very late stage of it. Above the Forest-bed, but beneath the oldest known Glacial deposit, there are sands and gravels, sparingly fossiliferous, and of still unsettled age. These strata between Bacton and Sherringham, include two distinct series—a marine bed characterized by *Leda myalis*, and a freshwater or flood deposit with Arctic plants. It is only in a few localities that either of the horizons is fossiliferous; and in the absence of fossils the separation of them from each other, and from the underlying Forest-bed, is a matter of considerable difficulty.

The marine deposit overlying the Forest-bed at West Runton has been known for many years, but its exact relation to the Crag and to the Glacial Beds is still an open question. The name "*Leda-myalis* Clay" was first used, as a local term applied to this section, by Prof. W. King in 1863,* and it has since been adopted for the horizon between the Upper Freshwater Bed of the Forest-bed Series and the Arctic Freshwater Bed. At present very little is known about its fauna, for the deposit is sparingly fossiliferous; but the fossils that do occur are generally found in colonies in the position of life. It is this stratum that has often, though erroneously, been correlated with the Bure Valley Beds, and has led some to place the Norwich Crag over the Forest-bed.

The *Leda-myalis* Bed usually consists of fine false-bedded loamy sand with grains of Chalk, thin seams of loam or clay, and

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* *Geologist*, vol. vi., p. 160.

a little gravel. The whole deposit, which nowhere exceeds 20 feet in thickness, is more constant in lithological character than most of the associated beds.

In the immediate neighbourhood of Weybourn no trace of this horizon has yet been found, and the first fossiliferous section occurs about 700 yards west of Old Hithe. Here, above the shelly Weybourn Crag, may be seen a bed of stiff blue clay with fragments of oysters; but as there is much talus on each side of the section, and a glacial disturbance also affects the beds, it is impossible to trace the clay more than a few yards.

Though unfossiliferous sections under Skelding Hill have been doubtfully referred to this horizon, no exposure showing either fossils or satisfactory stratigraphical relations, occurs in this neighbourhood till we arrive at a point a quarter of a mile west of Lower Sherringham, and nearly under the stile at the edge of the cliff. Unfortunately at this point there are constant land-slips, and all that can definitely be made out is, that, resting directly on the Weybourn Crag, and lying in a basin eroded through the Forest-bed, there is a mass of sand and small gravel, the lower 5 feet of which is full of oysters with the valves united. The character of this deposit indicates a depth of water of at least 5 fathoms, probably of about 10; while the underlying Weybourn Crag is a shallow-water bed formed at or just below low-water mark. This oyster bed thins out rapidly both east and west; for though so thick in the centre, and full of fossils, no shells are seen in it 20 yards away in either direction. Owing to the mud streams and constant slips, it has not been possible properly to examine the section, but it is likely to yield an important fauna. The shells are difficult to extract, being saturated with water and tender, but when dried they harden, and will bear handling. The species obained were :—

Littorina littorea.	Mytilus edulis.
Natica, sp.	× Ostrea edulis.
Purpura lapillus.	Tellina balthica.
Cardium edule.	——— obliqua.
× Cyprina islandica (young only).	× Balanus, sp.

Those marked × had the valves united. A few yards both to the right and to the left the clays of the Forest-bed come on between the Weybourn Crag and the *Leda-myalis* Bed.

The next fossiliferous exposure is at Beeston, where gravelly sand with occasional scattered marine shells, can be seen in vertical section definitely between the Upper and the Arctic Fresh-water Beds, all the deposits being fossiliferous. The only shells that could be found here were *Tellina balthica* and fragments of *Cyprina islandica*.

From Beeston to Cromer the stratum appears to be continuous, except where cut out by the Boulder Clay, but the only fossiliferous sections are at West Runton, and between that place and Wood Hill. At West Runton on each side of the Gap is found

the bed with *Mya truncata*, so often alluded to by different authors, and first mentioned by Trimmer in 1845.* The section on the east side of the Gap is :—

		Feet.
Soil		8
Contorted Drift	Contorted stony loam, marl, and sand	30
Leda-myalis Bed	Fine false-bedded sand with thin seams of loam, and gravelly base full of shells	15
Upper Freshwater Bed	Freshwater sand and peaty loam ; full of shells	1
Forest-bed (estuarine)	Weathered loam with roots and fragments of marine shells (Rootlet Bed)	?

The following species of mollusca were found in the *Leda-myalis* Bed ; but here, as at Sherringham, the exposure has been obscure for several years :—

Buccinum undatum, Linn.
Littorina littorea, Linn.
——— rudis, Maton.
Purpura lapillus, Linn.
Trophon antiquus, Linn.
——— ——— reversed var.
Natica catena? Da Costa.
×Astarte borealis, Chem.
Cardium edule, Linn.
Cyprina islandica, Linn.
×Leda myalis, Couth.
×Mya truncata, Linn.
Mytilus edulis, Linn.
Ostrea edulis, Linn. (fragment).
Tellina balthica, Linn.

The species marked × were found in the position of life with the valves united. Trimmer also mentions *Tellina obliqua*, *Mya arenaria*, and *Natica helicoides* from this spot. Besides these marine species, the bed contains a good many freshwater forms, evidently washed out of the sands two or three yards away.

Under Wood Hill a few scattered shells have also been found, including a single valve of *Tellina obliqua* ; though the bed is generally from 10 to 15 feet thick, fossils are rare and confined to the base.

To the south-east of Wood Hill, the *Leda-myalis* Bed can be traced as far as Cromer with the same lithological character, but no fossils have yet been found in it. During some alterations to the cellar of a house on Cromer sea-wall the sands were well shown, though neither the top nor bottom was exposed. Between Cromer and Kirby Hill, unfossiliferous sections can be seen whenever the cliff is free from talus ; but the bed is becoming attenuated, and towards Beck Hithe it appears to thin out altogether against the Boulder Clay.

Though the horizon may be represented by unfossiliferous sands in several places, it has not been recognized elsewhere. The deposit at Mundesley, formerly correlated with the *Leda-myalis* Bed, is now known to belong to the Forest-bed, and to underlie the Upper Freshwater Bed. The overlying sands probably form part of the Arctic Freshwater Bed.

* On the Cliffs of the Northern Drift on the Coast of Norfolk, between Weybourne and Happisburgh.—*Quart. Journ. Geol. Soc.*, vol. i., p. 218. *Proc. Geol. Soc.*, vol. iv. p. 435.

The evidence on which the different isolated sections have been correlated is not satisfactory. Besides the want of continuity of the deposits, there is the difficulty, first pointed out to me by Prof. Otto Torell, that the bed of oysters at Sherringham can scarcely be of the same age as the gravel with *Leda myalis* and *Astarte borealis* at Runton. The oyster is sensitive to cold, and does not now live in the seas that support these arctic mollusca. Oysters are, however, abundant in the Nar Valley Beds associated with certain arctic species. It is possible that the different sections of the *Leda-myalis* Bed are fragments of the marine deposits belonging to a period of considerable length, during which the depth of water varied and the climate changed. The alternate piling up and scouring away of sandbanks would cause sometimes one, sometimes another horizon to rest on the Forest-bed—just as we have seen that different zones of Red Crag may overlap on to the London Clay.

From its unconformity with the underlying and overlying freshwater strata, and from the small fauna yet obtained, it is impossible at present to say definitely whether the *Leda-myalis* Bed is more allied to the Crag or to the Glacial deposits. Of the fossils it is only safe to take into account those that seem undoubtedly to belong to the deposit. The reversed *Trophon antiquus* and *Tellina obliqua* occur, unfortunately, so rarely, and under such circumstances, that there is a suspicion of their being derived from the underlying Forest-bed or Weybourn Crag. Only about ten species of mollusca are undoubtedly contemporaneous with the deposit. One of these, *Leda myalis*, is an arctic species unknown in the Crag.* Another, *Ostrea edulis*, is not found in the Weybourn and Chillesford Crag, though common lower down.

No additions have been made to the fauna of this deposit for several years, but till further evidence is obtained, it seems most convenient to include the *Leda-myalis* Bed in the Pliocene Series—as was done in the Cromer Memoir.

The Arctic Freshwater Bed must certainly be classed with the Pleistocene deposits. It is described here, because of the great difficulty found in separating it from the *Leda-myalis* Bed, and from the Forest-bed, in the absence of fossils. It also helps to connect stratigraphically the Pliocene and Pleistocene formations; but its fossils, so far as known, differ so completely from those of the Forest-bed, and are so thoroughly Arctic, that there must be a considerable palæontological break between the two horizons.

During a visit to England in the year 1872, Prof. A. G. Nathorst, of the Geological Survey of Sweden, discovered, immediately under the Till at Mundesley, a bed of clay and

* All the specimens found in the Crag belong to *Leda oblongoides* of Wood, not to *Leda myalis*. The latter seems to be unknown on this side of the Atlantic, except in the *Leda-myalis* Bed.

loam containing *Hypnum turgescens* and leaves of *Salix polaris*.* No further account of this stratum appears to have been published till 1880, when, in a short paper in the Geological Magazine,† I showed that it is separated from the Forest-bed by the marine *Leda-myalis* Bed, and placed it, on account of the very arctic character of the climate it showed, at the base of the Pleistocene Deposits under the name "Arctic Freshwater Bed."

During the progress of the Geological Survey, the Arctic Freshwater Bed was discovered at two new localities about 14 miles apart,—at Beeston, and at Ostend, near Bacton. From the uniform character of the deposit, and from the way it appears to be cut out by the Boulder Clay, there is very little doubt that the three known exposures represent isolated patches of a once continuous and important deposit.

No sections of the bed have been seen near Weybourn, but at Lower Sherringham, on each side of the village, directly under the Boulder Clay, there are sands and thin loams with *Succinea* and occasional *Pisidia*, which probably represent this stratum.

At Beeston for a considerable distance, in fact till the Boulder Clay cuts through the beds to near the beach line, sands and loams with occasional freshwater shells occur about 10 or 15 feet above high-water mark, and immediately under the Boulder Clay. At one point, midway between Beeston Hill and the small stream, there is a lenticular mass of laminated peaty loam, which has yielded well-preserved plant remains, including moss and numerous leaves of *Salix polaris*.

The loam seems to occupy a channel, for during 1889 a new section was observed, in which several feet of bedded blue loam occurred directly over the carbonaceous Forest-bed. A sample of this loam was taken, under the impression that it belonged to the Forest-bed. On examining it afterwards in London it was found, however, that it must represent the base of the higher zone. It was full of mosses (not yet determined), and contained leaves of the Arctic birch and willow (*Betula nana* and *Salix polaris*). It also yielded fruit of a number of plants not previously known from the Arctic Freshwater Bed, so that in this seam we may perhaps have a flora less arctic than that higher up and immediately under the Boulder Clay.

Another more difficult question was raised by this exposure. Is it perfectly certain that the loam with Arctic plants does not lie beneath instead of above the *Leda-myalis* Bed? Unfortunately the two deposits have not yet yielded *characteristic* fossils at the same locality. I am now less inclined to attach importance to scattered marine shells, than when the Cromer Memoir was written. It is clear that fragments of derivative marine shells occur occasionally in the Arctic Freshwater Bed; perhaps the shelly sands usually found between the two fresh-

* *See* Lyell, Antiquity of Man, 1873, pp. 261, 262; and *Journal of Botany*, N.S., vol. ii. p. 225. (1873.)

† *Geol. Mag.*, dec. II., vol. vii., p. 548.

water deposits at Beeston do not really represent the *Leda-myalis* Bed. It seems probable that the succession published in 1880* is the correct one, for the fossiliferous Arctic Freshwater Bed can always be traced continuously upwards, till cut off by the Boulder Clay. The two seams undoubtedly belonging to the *Leda-myalis* Bed both lie some distance below the Boulder Clay and rest on Pliocene Beds. No arctic plants have, however, yet been found directly over the marine beds at West Runton or Sherringham. The age of the unfossiliferous sands and gravels which, at these localities, separate the marine bed from the Boulder Clay, is therefore still uncertain.

No other locality for the arctic plants is at present known west of Cromer. Several of the loams at Beeston and Sherringham have a rather weathered appearance, and seem to have been penetrated by small roots, such as might belong to the dwarf birches and willows. This evidence of ancient land-surfaces is thoroughly in keeping with the amphibious character of the mollusca, which remind one much of those of the loess of the Rhine, the land forms being only such as ordinarily live on alluvium, and can survive submergence for a limited time, while the freshwater species can live in damp mud. The species found were *Succinea putris, S. oblonga, Helix hispida? Valvata piscinalis,* and *Pisidium henslowianum.*

Though it is probable that further search may lead to the discovery of localities for the Arctic Freshwater Bed near Cromer, at present there is an interval of about nine miles to the next exposure. This was found nearly a mile west of Mundesley, where the section shown in Fig. 40, p. 166, was exposed about the year 1876.

In the Cromer Memoir beds 3 and 4 were referred to the Forest-bed Series, but at that time the plants had not been examined, the specimens having miscarried. It is now found that among them are leaves of *Salix polaris* and *Betula nana,* proving that the deposit belongs to the Arctic Freshwater Bed. From this point eastward to Mundesley the Arctic Freshwater Bed appears to be continuous, though only sparingly fossiliferous. A short distance north-west of Mundesley, in the original section discovered by Prof. Nathorst, the details vary continually, but at one of the most fossiliferous spots, immediately under the rain-water spout between the Coast Guard Station and the road to the Manor House, the following series of deposits occurs:—

		Feet.
2nd Till	Boulder Clay, full of chalk. Hard blue loam and a little sand	3
Arctic Freshwater Bed.	Stiff blue clay with moss, *Hippuris vulgaris, Salix polaris,* elytra of beetles, *Succinea putris, S. oblonga, Pupa muscorum,* and bones of *Spermophilus*	1½
	Sand and blue loam, contorted together; freshwater shells, *Pisidium amnicum?*	

* *Geol. Mag.*, dec. II., vol. vii., p. 548.

The *Spermophilus*, at present the only vertebrate known from this horizon, was found a few inches under the Boulder Clay in digging out a lump of the freshwater clay to wash for plant remains.* The specimen was much crushed; in fact, though it was probably nearly a whole skeleton, the only recognizable parts were a few teeth, tail-vertebræ, and foot-bones; and the thin seam of sand in which it occurred was flattened to about an eight of an inch. By drying and washing the clay through a sieve the leaves can be obtained uninjured, and so well preserved that the twigs of *Salix polaris* retain their original glossy chocolate-brown color. The leaves and moss may be dried in ordinary botanical paper.

Unfortunately the continuation of this deposit, both eastward and westward, is much obscured by talus, and where plants are absent the shells alone are not sufficient to show whether the bed belongs to the Arctic Freshwater Bed or to the upper part of the Forest-bed.

About eighty yards north-west of the Gap near Ostend Brick-kiln, Bacton, when the beach is very low, and the base of the Boulder Clay can be examined, the Arctic Freshwater Bed is again seen. The section is as follows:—

		Feet.
Soil		3
Till	Bedded marl, much piped	2
	Laminated sand and loam	3
	Hard Boulder Clay with little Chalk	5
Arctic Freshwater Bed.	Hard bedded blue loam, sand, and gravel: Arctic plants in the loam, *Salix polaris*, *Betula nana*, &c.	2+

This section was only once seen. After a severe gale the beach was exceptionally low, and a good exposure of the loam was laid bare at the foot of the cliff. Several species of plants were then obtained from it, but a few days later it was entirely hidden, and has not since been uncovered. The base of the Till is low at Ostend, and the beach exceptionally high, so that the deposits immediately under the Boulder Clay are, as a rule, entirely hidden, and there is also a considerable thickness of beds always obscured by the slope of the beach. The connection of the Arctic Freshwater Bed with the Upper Freshwater Bed seen near low-water mark, has not yet been made out. For about 300 yards north-west of the Gap, freshwater beds have been seen here and there at the base of the cliff; but further observations are needed before they can be definitely referred to this horizon; they may belong to the Forest-bed.

Though the term "Freshwater Bed" has been used in this Memoir for the stratum containing the Arctic plants, the deposit may perhaps be more accurately described as a flood-loam or sand, for the greater part of it does not appear to have been permanently under water, the most abundant shells being

* *Vide Geol. Mag.*, dec. II., vol. iv., p. 51. (1882.)

Succineæ, and not aquatic species. No sections of the Arctic Freshwater Bed are yet known except the four already described.

The similarity of lithological character in all the deposits immediately beneath the Boulder Clay has necessitated the inclusion of the Arctic Freshwater Bed in the Pre-glacial Series in the separate Sheet of cliff sections*; but in the present Memoir it has been placed at the base of the Pleistocene Series, because the change from the climate of the Forest-bed, shown by the plants, is so great that it seems a misnomer to speak of the bed as "Pre-glacial." In this bed trees have entirely disappeared, and its plants include the dwarf Arctic birch and Arctic willow. Its fauna and flora show the first incoming of Arctic *land* species†, and indicate a lowering of the temperature by about 20 degrees,—a difference as great as that between the South of England and the North Cape at the present day, and sufficient to allow the seas to be blocked with ice during the winter, and to allow glaciers to form in the hilly districts.

The whole of the strata lying between the Cromer Forest-bed and the oldest Boulder Clay on the Norfolk coast, seem referable to one or other of the two horizons just described as the *Leda-myalis* Bed and the Arctic Freshwater Bed. There are, however, wide sheets of pebbly gravel about which nothing can be said, except that they lie between undoubted Pliocene strata and undoubted Glacial deposits. These gravels probably belong to several different horizons. Some of them appear to be shore deposits of the age of the Weybourn Crag, others may be coeval with the Forest-bed. Littoral equivalents of the *Leda-myalis* Bed may also be represented; and perhaps there may also be relics of still other horizons, of which the fossils are entirely unknown. Under these circumstances little can be done, except to give an outline of the distribution and general character of the deposits, and to indicate the few localities where more definite evidence may be obtained.

A glance at the Geological Survey Map of the neighbourhood of Cromer, (Sheet 68 E.), will show that Pliocene deposits are traceable between Bacton and the River Ant at Honing. The strata immediately under the Boulder Clay at Bacton are generally the quartzite-gravels, quartzose sands, and laminated loams of the Forest-bed, and it is probably to this division of the Newer Pliocene that all the sections between Bacton and Honing belong. Similar gravels occur at Worstead; but the further they are traced from the coast the more difficult does correlation become. No fossils have been found in this area, except at Honing, where the eight species of mollusca recorded by Mr. H. B. Woodward are insufficient to fix the age of the deposit. It may

* Horizontal Section, Sheet 127 (*Geological Survey*).

† The Glutton and Musk Ox are the only arctic land species yet known from the Forest-bed (*see ante*, p. 182).

belong either to the Weybourn Crag, or to the Forest-bed, (see p. 137).

A considerable area occupied by similar pebbly gravel has been mapped on the low land between Hickling and Barton Broads, and in the adjoining portion of the valley of the Bure. There is little doubt that these overlie the Chillesford Clay, but this is all that can be said about them. In the upper part of the Bure Valley the pebbly gravels are quite inseparable from the Norwich Crag, and have already been described with that formation.

Around Norwich pebbly gravel with seams of laminated clay commonly overlies the undoubted Norwich Crag. As a rule these strata are unfossiliferous, but at one or two points seams of ironstone contain casts of shells. This appears to show that the absence of fossils at other localities is merely due to the complete decalcification of the gravels. No evidence has yet been obtained that will justify the correlation of the pebble gravels near Norwich, with one rather than another of the divisions noticed on the coast. The strata can be well seen at the Bishop's Bridge, or Lollard's Pit, in Norwich. Here Prof. Prestwich describes them as "white sands, and flint shingle (Westleton beds)," and gives the thickness at 20 feet.* At the pit at Thorpe Kiln, casts of shells occur in a seam of ironstone above the Chillesford Clay. The species recorded by Mr. H. B. Woodward† are :—

Littorina littorea.	Mytilus edulis.
Purpura lapillus.	Nucula Cobboldiæ.
Cardium edule.	Tellina balthica?
Modiola (large sp.).	——— obliqua.
Mya arenaria.	

There is nothing in this list to fix the age of the deposit, as *Tellina balthica*, the only species of importance from this point of view, is a doubtful determination.

Near Reedham the shingle so conspicuous in the railway cuttings, forms a mass of 25 feet or more in thickness, and seems to lie between the lower Boulder Clay and the Chillesford Clay. In composition it consists mainly of flint, pebbly and subangular, and quartz pebbles. The sections of it, fully described by Mr. Blake in the Norwich Memoir, throw no light on the question of the age of the gravels. Around Beccles the deposits are more sandy, though otherwise similar. The pebble gravels are often cut out or overlapped by newer strata between Beccles and Bungay, and seldom rise to any great height above the marsh level.

In the tributary valley that extends from Ditchingham westward to Bedingham, the gravels become of greater interest, for though still unfossiliferous, their lithological character is singularly like that of the Forest-bed gravels at Bacton (see p. 170).

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* *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 462. (1871.)

† Geology of the Country around Norwich (*Mem. Geol. Survey*), p. 75.

As they rise to a height of 30 feet above the sea, they can be well examined. At Hedenham they consist of greenish-grey pebbly sand, exposed to a depth of five feet. More than half the pebbles are foreign to the district, principally quartz, and a large number of quartzite. At Woodton were found fine false-bedded pebbly gravel and sand, in the lower part of which was a good deal of greenish clay. About half the pebbles were of flint, the rest consisted of hard sandstone, quartz, and quartzite. One pebble of Hertfordshire pudding-stone was noticed. This correspondence in composition between the gravels at Woodton and those in the Forest-bed at Bacton is worthy of notice, especially as in the intervening area they are to a much larger extent of local origin. Is it possible that we are really dealing with two distinct horizons, and that the Woodton gravels are truly of the age of the Forest-bed, whilst the shingle at Reedham is of later date? The occurrence of the peculiar light-coloured fine-grained quartzite so abundant in the Forest-bed is, however, insufficient to prove that the Woodton gravel is of Forest-bed age. Similar quartzite pebbles are found rarely throughout the Upper Pliocene series in Norfolk, and are merely more abundant in the estuarine gravels than in the marine ones. Some large pebbles were found in the shingly Norwich Crag at Ditchingham (see p. 111).

Higher up the Waveney Valley somewhat similar deposits have been mapped by Mr. Dalton in the neighbourhood of Withersdale. The beds have here become more loamy and sandy.* A section in Withersdale brickyard showed 25 feet of laminated loams, alternating with pebble gravel, resting on rather loamy sands. South of the Waveney Valley, little difficulty has been felt in separating the pebble gravel from the Crag. It is therefore shown on the Geological Survey Map as a distinct division, coloured differently.

Returning to the coast, we find no deposits older than the lower Boulder Clay for several miles south of Happisburgh. Near Hopton, north of Lowestoft, the Rootlet-bed again rises above the sea-level, but is cut off above by Boulder Clay. Not many yards further a series of pebbly sands comes in between the Boulder Clay and the Rootlet-bed. These sands can be traced continuously nearly to Corton Gap, near which place Boulder Clay again ploughs through the bed. Mr. Blake describes the "Pebbly Series" in these cliffs as consisting of "buff and ash-coloured pebbly sands, containing patches of clay and ferruginous concretions, laminated or well-stratified grey and brown clay, and ferruginous gravel and sand ('pan'), particularly at its base, where also a little ochreous-coloured clay occasionally occurs overlying the black peat. No fossils have been observed in any portion of this deposit at Corton."†

* *See* Geology of Halesworth and Harleston. (*Mem. Geol. Survey*), pp. 15, 16.

† Horizontal Sections, Sheet 128. (*Geological Survey*); and Explanation 8vo. p. 6. *See also* Geology of the country near Yarmouth and Lowestoft. (*Mem. Geol. Survey.*)

Similar pebbly sands reappear in the Pakefield and Kessingland Cliffs, resting sometimes on the Forest-bed, sometimes on Chillesford Clay. Owing to the absence of any intervening Lower Boulder Clay, this series is not very distinctly separated from the Middle Glacial Sands, though the line of junction can usually be traced. The lithological character of the sands is the same as at Corton, except that now they contain derivative pebbles of the underlying Chillesford Clay.

We now enter the district taken by Prof. Prestwich as the typical area for his "Westleton Sands and Shingle," a name afterwards changed to "Mundesley and Westleton Beds."* The latter term it is impossible to adopt, for there is no evidence that the strata at Westleton are connected with those at Mundesley. On the Norfolk coast Prof. Prestwich's group includes part of the Weybourn Crag, part of the Forest-bed, the *Leda-myalis* Bed, and the Arctic Freshwater Bed—a collection of zones which have nothing to do with each other, and do not even form a continuous series. The Forest-bed, though placed by Prof. Prestwich below his Mundesley Beds, is really in the middle of this group, many of his illustrations being taken from the estuarine division. The name "Westleton Beds" might possibly be useful for the deposits immediately around Westleton and Southwold, for these most probably belong to one series. In the absence of any clear stratigraphical continuity of the deposits, and of any characteristic fossils, we cannot, however, use the name in any more extended sense. In this Memoir I have followed Mr. Whitaker in using the indefinite term "Pebbly Series" for the large residuum which remains, after all deposits of determinable age have been separated. The following description of this area is mainly condensed from the Memoirs by Mr. Whitaker, who surveyed the district.† We will commence with the cliff at Covehithe and trace the sections southward.

In Covehithe cliff pebbly gravel and sand reappear. They rest on Chillesford Clay, in places with a fairly even junction, in others irregularly. No shells have yet been found here. The Easton Bavent cliff shows the Pebbly Series gradually cutting through the clay towards the south, but at the same time resting on it with amore even junction. At Southwold the Chillesford Clay has entirely disappeared, so that there is considerable difficulty in separating the Pebbly Series from the underlying shelly Crag. This is one of the few localities where fossils have been recorded from the Pebbly Series. There seems, however, to be considerable doubt whether the shelly beds do not belong rather to the underlying Crag. The localities where fossils occur will therefore be described fully. The most northerly section is shown in Fig. 47, from the Southwold Memoir.

* *Quart. Journ. Geol. Soc.*, vol. xxvii., pp. 461–463 (1871); and *Rep. Brit. Assoc.* for 1881, p. 620, *Geol. Mag.* dec. II., vol. viii., p. 466 (1881). See also *Memoirs Geol. Survey* on Norwich, Cromer, and Southwold.

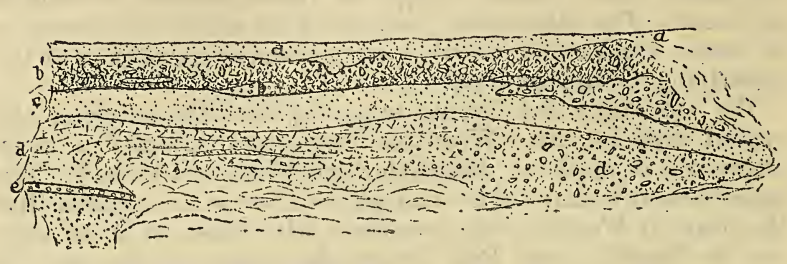
† *See* Geology of Southwold and the Suffolk Coast (1887); Geology of Halesworth and Harleston (1887).

Fig. 47.

Section in the Cliff, about 250 yards N.N.E. of the Coast Guard Flagstaff, at the Northern End of Southwold. 1878, 1879.

(W. Whitaker.)

S.W. N.E.



a. Sandy stony soil, about a foot.

Glacial Drift:

b'. Boulder Clay, weathered at top and with pipey masses of sand, rather dark, over 3 feet passing on the right into:—

b. Pale grey Boulder Clay up to 4 feet (or more?).

c. Light-coloured and brown sand, mostly coarse, sometimes a coarse grit, with gravelly layers; over 3 feet; passing into the next. ? = the Middle Glacial sand of Wood.

d. Sandy pale Boulder Clay (in the central part of the pit): on the left rather a loam and sand, with scattered stones; about 8 feet.

e. Gravel, chiefly of pebbles of flint, but many of chalk; some broken shells; nearly a foot. Differs from the pebbly gravel of the district in containing chalk.

f. Crag? Coarse ferruginous sand with broken shells, and so full of flint-pebbles as to be almost a gravel. Dug to a depth of 6 feet. Of course it is possible that this may be a shelly condition of the pebbly gravel; but the undoubted Crag hereabouts often contains gravel.

S. V. Wood considered bed *f* of this section to belong to the Pebbly Series, but remarked that "I call attention to it because I believe that *all* the shells in it are derivatives from the Crag . . ."* The deposit has yielded 23 species of mollusca, all common Norwich Crag forms.

The Pebbly Gravels occupy the whole of the Southwold island, except a small area near the section just described. They reach a thickness of 37 feet in the well at Waterworks. One other fossiliferous section occurs in the railway cutting at Southwold Station, where about 20 species of mollusca have been obtained—all common Norwich Crag forms. In the 2nd Supplement to the Crag Mollusca, S. V. Wood refers the shells to the 'Lower Glacial' (= Bure Valley Beds = Westleton Beds), but in the 3rd Supplement he corrects this, considering that all the species are derived from the underlying Crag. His later opinion seems more likely to be correct.

On the northern side of Buss Creek (the channel that separates Southwold from the mainland on the north-west) there were two

* Third Supp. to the Crag Mollusca—*Palæontographical Soc.*, pp. 23, 24.

other fossiliferous sections. One of these was in a small pit two-thirds of a mile north-north-west of Southwold Church, close to, and on the eastern side of, the road to Lowestoft. Here Mr. Whitaker obtained nine species of mollusca, but there is the same uncertainty as to their real age, as in the case of those from the Southwold sections. The other locality was discovered by Prof. Prestwich, who found "in a pit close to the north-east edge of Reydon marshes . . . . a seam of the same pebbly sand concreted by oxide of iron. This seam was full of the casts and impressions of *Mytilus edulis* in all stages of growth, and many of the shells double."* Crag crops out near this spot, so the seam with mussels may belong to the lower strata, not to the Pebbly Series.

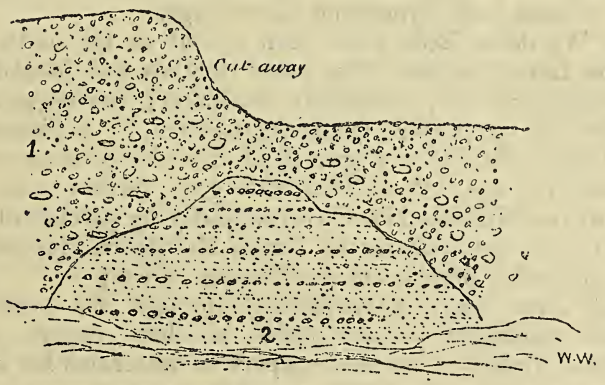
The sections of the Pebbly Series just described include all those in Suffolk that have yielded fossils. Evidence of the mode of origin, and of the age of the deposits, seem, therefore, to be entirely wanting. I cannot help agreeing with the last opinion expressed by S. V. Wood, that in this district only derived fossils are found. The one locality where mussels occur may be an exception.

Inland, west of Southwold, the Pebbly Series crops out on each side of the valley of the Blyth, some of the best sections occurring in the Wangford tributary valley. A pit near Wangford shows well the irregular junction with the glacial gravel, and also the difference of character between the two deposits (Fig. 48).

FIG. 48.

Section in a Gravel Pit N.E. of Wangford.

(W. Whitaker.)



1. Gravel and sand. The gravel irregular, composed largely of flint pebbles, but also with pebbles of chalk; partly coarse, and with large flints and other stones (Glacial Drift).
2. Sand, with layers of pebbly gravel, bedding flat, reaching up to about 8 feet above the bottom of the pit.

Near Halesworth station Mr. Dalton notes that the strata change to "a thick mass of grey pebbles, in a matrix of sand, a

* *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 462. (1871.)

large pit showing a thickness of 30 feet, with marked current-bedding. Above these pebbly beds, close under the Boulder Clay, and nearer to the station, light-coloured sand, bedded with layers of pebbly gravel, was seen at a spot now covered by the embankment of the Southwold line."*

It is in the district south of the Blyth that the Pebbly Beds take up most area (compared with other deposits), forming the level hill-tops, except for sundry mostly small cappings of Boulder Clay. But they are cut through everywhere by the valleys, which reach to the underlying sand, except in the case of that of the Blyth itself, in which the Pebbly Beds reach down to the marshes in three places, on the southern side.

There seems to be a good deal of difference of opinion as to the correlation of the strata seen in Dunwich cliffs; for the gravels referred by Mr. Whitaker to the Pebbly Series, are by Prof. Prestwich and S. V. Wood considered to be glacial. These pebbly gravels are almost confined to two portions of the cliff—the southern end, and close to Dunwich. The gravels are continuous inland for two and a half miles, as far as to Westleton, near which place they pass under the plateau of Boulder Clay, only occasionally to reappear in the deeper valleys. The "Westleton Sands and Shingle" in the typical locality are thus described by Prof. Prestwich.† "They attain a thickness of from 30 to 40 feet, and consist of a series of stratified beds of well-rounded flint-pebbles imbedded in white sand. They look more like the pebble-beds of Blackheath than any other beds in the eastern counties. Mixed with the flint-pebbles are a few small pebbles of old rocks, with a considerable number of white quartz-pebbles, the presence of which constitutes a distinctive feature of these beds throughout their range."

These Westleton Beds have been traced as far south as the Minsmere Level; beyond that point they are not identified by the Geological Survey, though Mr. Whitaker‡ has suggested the possibility of the gravel being represented, in a distant part of the London Basin, by a gravel of like character as well also as of doubtful age. Prof. Prestwich goes further, and correlates with the Westleton Beds various outlying patches of gravel scattered over the counties of Essex, Middlesex, Hertfordshire, Surrey, and other portions of the Thames valley.§

Whilst these pages were passing through the press, Prof. Prestwich published a new series of three papers on the "Westleton Beds."‖ In these papers he reiterates his already

* Geology of Halesworth and Harleston. (*Mem. Geol. Survey*), p. 15.

† *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 461. (1871.)

‡ Guide to the Geology of London. (*Mem. Geol. Survey.*) Ed. 3, p. 57 (1880,) and Ed. 5, pp. 58–60.

§ On the Extension into Essex, Middlesex, and other Inland Counties, of the Mundesley and Westleton Beds . . . . *Rep. Brit. Assoc.* for 1881, p. 620, and *Geol. Mag.*, dec. II., vol. viii., p. 466. (1881.) *See also* H. B. Woodward, Notes on the Bure Valley Beds and the Westleton Beds. *Geol. Mag.*, dec. II., vol. ix., p. 452. (1883.)

‖ *Quart. Journ. Geol. Soc.*, vol. xlvi., pp. 84–181. (1890.)

published views as to the classification and order of succession in the strata described in Chapters VIII., IX., and X. of this work, but brings forward no new evidence as to the relations of the different deposits It is, therefore, unnecessary to modify the classification adopted by the Geological Survey, especially as it was founded on a large amount of evidence which was not available when Prof. Prestwich's views were first brought forward. It may also be pointed out that the present Memoir contains much corroborative evidence, both palæontological and stratigraphical, which has only recently been obtained, through the systematic collection and study of the fossils, and through the making of trial-borings.

Some of the outliers referred to by Prof. Prestwich to the Westleton Beds have been coloured on the maps of the Geological Survey as glacial, and are also considered by Messrs. Wood and Harmer to belong to the Glacial series. These will not be described here. We will merely draw attention to those outliers mapped by the Survey as something differing from, and probably older than, the glacial deposits. The common characteristic of these outliers is that, unlike the other gravels, they contain a large proportion of pebbles of quartz and light-coloured quartzite. They usually occur at a considerable height above the sea. They overlie Bagshot Sands, and often can be seen to pass under the Chalky Boulder Clay, but their stratigraphical position cannot be more exactly fixed.

One of these outliers has been mapped near Hertford, by Mr. Whitaker, who speaks of a "small deposit of pebble-gravel that occurs on the London Clay hills between Hertford and Hoddesdon, and which may be of pre-glacial age. It is composed almost wholly of pebbles, the larger mostly of flint, and the smaller of quartz, and it has been inferred to be the oldest Drift-bed in the district (and to the west), and to have been largely denuded before the deposition of the succeeding bed."*

From Hertford these gravels extend in a south-westerly direction, capping all the higher hills as far as Rickmansworth. After an interval of a few miles they reappear on high ground near Amersham, and again, on the south side of the Thames, not far from Marlow. To the east small outliers are found on Hampstead Heath, at a height of about 400 feet above the sea. At High Beech the gravels reappear, and again on the highest points in the county, at Havering, Brentwood, Langdon Hill, and Hadleigh. Crossing the Thames, we find an outlier on Shooter's Hill and Swanscomb, which may be of the same age. As full details of all these outliers are given in a recently published Memoir,† it will be unnecessary to redescribe them here.

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* Geology of the N.W. part of Essex and the N.E. part of Herts, &c. (*Mem. Geol. Survey*), p. 32. (1878.)

† Geology of London, vol. I (*Mem. Geol. Survey*), pp. 290–296. (1889.)

Beyond the area already described, we find dotted over various parts of the south of England, small isolated masses of gravel, not entirely of local origin. These often cap the highest points. For instance, on the Blackdown and Haldon Hills, in Devonshire, they occur on plateaus 800 feet above the sea, separated from any other high land by deep valleys. Though many of these deposits are possibly of Pliocene age, it is useless to attempt any description of them here, for, for anything we yet know, they may be of any date from Eocene to Older Pleistocene. This question is now being worked out during the progress of the new Drift Survey.

One deposit, undoubtedly of Pliocene age, remains to be described—that at Dewlish, in Dorsetshire. This locality has been left till last, because though the bed seems to belong to the Upper Pliocene series, there is at present no sufficient evidence to settle its exact position. Geographically it is widely separated from the fossiliferous Pliocene deposits of East Anglia, and it is quite as much connected with certain deposits in France, which will be referred to in the next chapter.

Dewlish is a small village lying about six miles north-east of Dorchester, in the middle of the Chalk Downs. A long dip-slope causes the height of the Downs to fall towards the south, and the gravel now to be described lies about three miles from the edge of the Chalk escarpment; and at a much lower level. The Eocene strata a short distance to the south rise to about the same height as the gravel.

The history of the discovery of elephant remains at this spot is fully described by the Rev. O. Fisher.* It is curious that the occurrence here of *Elephas meridionalis* should have attracted so little attention, but the specimens first found were referred by several competent observers to *E. antiquus*. Thus they excited less interest than would otherwise have been the case. Teeth of elephant were found as long ago as 1813, and in 1870 the species was recorded as *Elephas meridionalis*, on the authority of Mr. Ayshford Sanford.† During 1887 Mr. Fisher took up the question, and he and Mr. Mansel-Pleydell made excavations which showed the character of the deposit, and led to the discovery of more bones. More recently I have examined the surrounding district, for the purpose of ascertaining the relation of the gravel to the existing contours, and to see what connection might be traced between the Pliocene strata and the present lines of drainage.

The locality from which the bones were obtained lies close to Dewlish, but on the opposite (east) side of the Devil's Brook, the exact spot being 150 yards north-east of the foot-bridge. Above the stream there is a steep bluff of Chalk, with the unusually high slope of 25°, facing the village. This bluff rises to a height

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* *Quart. Journ. Geol. Soc.*, vol. xliv., p. 818. (1888.)
† Flint Chips, by Joseph Stevens. 8vo. London, 1870.

of a hundred feet above the brook. From the top of the scarp, the surface, instead of continuing to rise at a less angle, falls gently and steadily to the eastward, towards an adjoining valley, now quite dry. On the west side of the Devil's Brook this gentle inclination seems to be continued upward on the next ridge, quite independently of the valley now intervening. The steady slope, agreeing with the trend of the Eocene strata, apparently shows that there is a dip-slope to the south-south-east. This is an important point, for it at once explains the steepness of the bluff on the east of the Devil's Brook, compared with that on the opposite side. The steep bank, as is generally the case, shows that the strata here dip into the hill; the gentle slope shows that they dip towards the stream.

The excavation made by Mr. Mansel-Pleydell was close to the summit of the bluff, the top of the hill being cut into until work was stopped at the hedge of an adjoining wheat field. This explanation is necessary, for the diagram section in Mr. Fisher's paper shows the mammaliferous gravel apparently clinging to the steep slope of the bluff. Mr. Pope, who superintended the excavation, informs me, however, that there was no sign of the deposit dying out, for the work ceased with a high vertical face of sand and gravel. Work was stopped, not because the bed had died out, but so that the hedge and growing wheat should not be damaged. Mr. Mansel-Pleydell's section is:—

Mould	about 3	inches.
Chalk rubble	10	,,
Fine impalpable sand and flints, remains of elephant	3	feet.
Sand and ferruginous gravel	?	
Flint material, water-borne	?	
Sand, the lower portion with different-sized flints	?	
Chalk.		

Both Mr. Fisher and Mr. Mansel-Pleydell are of opinion that the material is water-borne, and is not merely the contents of a pot-hole. Many of the flints are worn and polished in an unusual way, explained by Mr. Fisher as probably "due to the long-continued percolation of water, carrying fine silt with it." The polishing is so marked that some of these flints have been placed in the Museum of Practical Geology, where they will be seen to present many points of resemblance to rock-surfaces that have been polished by wind driving sand across them. The gravel also contains small quartz pebbles, which must have travelled from a considerable distance.

Mr. Fisher considers the gravel at Dewlish to belong to an old river terrace, cut when the Devil's Brook flowed 90 feet higher than it does at present. An examination of the surrounding country leads me to suspect, however, that the gravel has nothing to do with the present minor lines of drainage. The deposit caps a ridge lying between two valleys, and if it belongs to any existing valley, it seems rather to be to the dry coombe east of the Devil's Brook. The general slope of the Chalk surface trends

in that direction, and the present stream is probably of much later date. Some details of the contours are suggestive of an ancient valley trending east and west; that is to say, at right angles to the present lines, but nothing more can be said about this until the whole country has been gone over in detail.

A considerable number of bones and teeth of elephant have been found, but as yet no other fossils. Some of the molars are considered by Mr. Mansel-Pleydell* and Mr. E. T. Newton to belong to *Elephas meridionalis*. Others correspond closely with specimens from the Cromer Forest-bed, often referred to the broad-plated variety of *Elephas antiquus*.

The occurrence of *Elephas meridionalis*, elsewhere in Britain confined to Upper Pliocene strata, and perhaps of another elephant characteristic of the Cromer Forest-bed, suggests that the Dewlish gravels may be of Forest-bed age. At present, however, the evidence is insufficient definitely to decide this question, for *Elephas meridionalis* perhaps occurs in later deposits in France and in Italy.

This completes the account of the British Pliocene strata. The so-called "Bridlington Crag" is not Pliocene, but Pleistocene, though it contains some extinct Crag shells, like *Tellina obliqua* and *Nucula Cobboldiæ*.† In Scotland no Pliocene strata have yet been discovered in place, though specimens of *Voluta Lamberti*, *Turritella incrassata*, *Nassa reticosa*, and *Astarte mutabilis* occur in the glacial deposits of the Aberdeenshire coast; pointing, apparently, to some deposit of Red Crag age, lying beneath the North Sea, from which they were derived.‡ Certain deposits around Lough Neagh, in Ireland, have been called Pliocene, but there is no evidence to justify their reference to this Series. In the next chapter an attempt will be made to trace the Pliocene strata beyond the limits of these Islands.

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* Note on Elephas meridionalis, found at Dewlish. *Proc. Dorset Nat. Hist. and Antiq. Field Club*, vol. x., pp. 1–18. (1889.)

† See Crag Mollusca, 4to., *Palæontograph. Soc.; Quart. Journ. Geol. Soc.*, vol. xl., pp. 312–328; and Geology of Holderness, (*Mem. Geol. Survey*), pp. 8–26. (1885.)

‡ See Jamieson, On the Crag Shells of Aberdeenshire . . . . *Quart. Journ. Geol. Soc.*, vol. xxxviii., pp. 145–159. (1882.)

§ See Hardman, Fossiliferous Pliocene Clays overlying Basalt, near the Shore of Lough Neagh. *Geol. Mag.*, dec. II., vol. iii., p. 556–558, and vol. vi., pp. 211–216; also Swanston, On Supposed Fossiliferous Pliocene Clays overlying Basalt, near the Shore of Lough Neagh, *Ibid*, vol. vi., pp. 62–65.

CHAPTER XI.

FOREIGN EQUIVALENTS OF THE ENGLISH PLIOCENE STRATA.

THE study of any group of strata exclusively from the standpoint of a single limited area like Britain is likely to lead to wrong conclusions as to the real importance of each stratigraphical division, inasmuch as it proceeds on too narrow a basis and tends to blind us to the great imperfection of the record, and allows us to forget the fundamental truth that a gap in the strata, marked only by a line, may represent a longer period than the whole of the deposits that are now preserved. Especially is this the case when we study a group of shallow-water strata like the British Pliocene deposits, which in no one locality reach a thickness of 200 feet. When we think of the meaning of this small development the reason becomes obvious—the Upper Pliocene strata were deposited in such shoal water that no increase of thickness was possible, though the sediments were constantly being scoured out and redeposited. On the further side of the North Sea there is a great expansion of these deposits, for there, instead of a stationary area there was one of subsidence. We scarcely realise the true importance of the Pliocene period, however, till we see the enormous mass of the Sub-Apennine strata of Italy, and observe how large an area they cover.

It was felt that this Memoir would be made more complete by an examination of the corresponding deposits in other countries. There is great advantage also in being able to meet other observers, who look at things from a somewhat different point of view. And, lastly, the study of the fossils in foreign museums will often show that whole groups of species appearing under different names are merely somewhat modified representatives of well-known forms. In fact they are old geographical races, which are called species or varieties according to the personal bias of different observers.

During the spring of 1886 I had made a holiday visit to Auvergne and the south of France, for the purpose of examining the Pliocene strata; but the limited time at my disposal rendered it impossible to go further. Soon after I was delegated by the Director General to make the necessary journeys, and spent three weeks in Belgium, in company with Messrs. Van den Broeck, Cogels, and Van Ertborn. Opportunity was at the same time taken to visit Utrecht to meet Dr. J. Lorié and to examine the original specimens obtained from the deep borings

recently made in various parts of Holland. Next year another excursion was made by me, through France to Italy, mainly with the object of examining the marine Sub-Apennine deposits, and the lacustrine beds of the upper Val d'Arno. The route followed was through the Rhone valley and the Riviera, for I was desirous of judging to what extent the Alps might have formed a barrier to the migration of species in Pliocene times, and consequently what amount of resemblance we might expect between the Pliocene land faunas north and south of the mountains.

These journeys, though restricted to some only of the more important localities, have enabled me to form a better idea of the character of the Pliocene deposits of western Europe. In compiling the following notes I have taken advantage of the most recent work of the different national Surveys; but where the Surveys do not happen to be available, the account is either from personal observation or from the best Memoirs.

Anyone acquainted with the difficulties met with in a small area in England will understand that the correlation here adopted is only provisional, although formed after a study of the best evidence at present to be obtained. The views of foreign observers have not in all cases been accepted as to the correlation, but where I have ventured to differ from them, it has been on the ground that the particular horizon dealt with happens to be better represented or more fossiliferous in England, or its stratigraphical relations are here more clearly shown.

In dealing with foreign correlation it is necessary to divide the Pliocene deposits into two parallel series—the marine and the freshwater. The reason of this classification is obvious. A narrow isthmus may separate two quite different marine faunas, while the land and freshwater species are the same throughout the whole of the adjoining area. A strait, on the other hand, may prevent the mingling of different groups of land and freshwater forms, while allowing the marine to spread freely. It must obviously have made a great difference in the natural history and climate of the adjoining areas, whether there was a strait or an isthmus where we now find the Straits of Dover. We will therefore first deal with the marine strata and their fossils, and afterwards with the land-animals and plants. A similar division is adopted in the lists of fossils in the Appendix.

In Belgium and Holland the Pliocene period is only represented by marine deposits, which do not extend eastward into Germany, and are only traceable a short distance southward into France. Whether they ever extended across the Bas Boulonnais towards Paris, is unknown, for the same line of disturbance which has affected the Weald, and has caused the Lenham Beds to end so abruptly, has cut off the Diestian group not far from Calais. The correlation of the Pliocene strata of Belgium with those of England, involves no great difficulty, and the subject has already been alluded to in previous Chapters. There seem to be

two divisions; the lower, or Diestian, representing our Coralline Crag and Lenham Beds; the upper, or Scaldisian, equivalent to the lower part of the Red Crag, or Walton Crag. The higher zones, preserved in Norfolk and Suffolk, are at present unknown in Belgium and Holland.

A wide interval separates the Pliocene strata of the Anglo-Belgian basin from the nearest marine deposits which can be referred to the same period. Correlation thus becomes much more difficult. The marine deposits of Cotentin, in Normandy, seem approximately to represent the Pliocene clays of St. Erth, in Cornwall. Both these are probably Older Pliocene, though belonging to the north European type of that series, and not to the Mediterranean basin. The next marine deposits met with are of the Mediterranean type, and we can no longer attempt any detailed correlation with the English Crags. Perhaps the character of the Pliocene strata of the south of France will be best understood from the following translation of the excellent account given by Prof. A. de Lapparent.*

The Miocene period was characterised by the wide expanse of the sea, which sent long tongues up the valleys of the Loire and Rhone, and covered parts of Switzerland and Austria. Thus Europe was transformed into a kind of Indian archipelago. At the commencement of the Pliocene period, as Prof. de Lapparent remarks, the geography of the Mediterranean region had undergone a transient but considerable modification. The earliest deposits of this age tell of conditions more brackish-water than marine. Beds with *Congeria* spread over various parts of Provence, of Italy, and of Corsica, at the same time occupying considerable areas in eastern Europe, proving how at that time the Mediterranean did not extend beyond the meridian of Sardinia, and that all its eastern part had given place to a series of Caspian Seas, on the borders of which large troops of herbivora ranged freely. But soon the contours of the region became more pronounced, the continuity of marine conditions became re-established, and the sea advanced, by long channels, beyond the present estuaries of our rivers, notably in the valley of the Rhone, where it formed a kind of fjord, of which the extremity reached the gates of Lyons, and in that of the Po, where it penetrated as far as Ivrea and Mondovi. During this epoch, in various parts of western Europe, imposing volcanic manifestations prolonged the eruptive activity of the Miocene period. Under these influences, a climate relatively very mild permitted Europe to support a vegetation in which the types of the rich forests of the north are mingled with those of the Canary Islands, and of the borders of the Caucasian region. But the temperature sank little by little, at the same time that the sea retired; the flora became impoverished never to recover; the most delicate species migrated towards the south, and palms

* Traité de Géologie, 2nd edit., 8vo., 1885, pp. 1210–1211.

were no longer found except in latitudes lower by 10 degrees than those which they had attained during the Miocene period. At last the period closed with a flora which, though still sufficiently rich to funish abundant food for gigantic herbivora, no longer contained, at each point, species which it is easy to-day to rediscover by approaching some degrees nearer towards the equator.

In this outline of the climatic changes in the Mediterranean region Prof. de Lapparent traces a gradual refrigeration of the climate corresponding to that which we have seen is so marked in England. It appears, therefore, that a classification of the Tertiary strata founded on important climatic changes, ought to be of more than local value. It ought also to yield a better standard for the correlation of isolated deposits than can possibly be found in the variable and uncertain per-centage of recent mollusca discovered at each locality.

The Pliocene system in the south of France is commonly thus divided* :—

Upper (*Arnusian*)	Horizon of Saint-Prest with *Elephas meridionalis* -	=Forest-bed.
	Horizon of Perrier with *Mastodon arvernensis* - -	=Norwich Crag and Upper Red Crag.
Middle (*Astian*) -	Freshwater beds with *Semnopithecus* and *Mastodon arvernensis* - -	=Lower Red Crag ?
Lower (*Plaisancian*)	Estuarine beds with *Potamides Basteroti* - -	=Coralline Crag.
	Marine beds with *Nassa semistriata* - -	
Mio-Pliocene ? (*Messinian*).	Brackish-water deposits with *Congeria* - - -	Missing in England.

The lowest of these divisions scarcely comes within the limits of this Memoir, for the horizon is unrepresented in Britain, though found in Belgium, where deposits apparently of about this age are generally referred to the Miocene period. In the basin of the Rhone, the Messinian strata rest unconformably on the older deposits, including the Miocene. They certainly in that district are more naturally grouped with the Pliocene series than with the older deposits, which according to M. Fontannes' sections have been greatly disturbed and eroded in the interval. The Messinian strata yield a brackish-water fauna, characterised by several species of *Congeria* and *Melania*, and the thickness of this division is small.

Above the brackish-water Messinian deposits come those known as Plaisancian—equivalent approximately to our Coralline Crag. These are separated by M. Fontannes into two groups ; a lower series of marine strata with *Nassa semistriata;* and an upper

* *See* Fontannes, Études Stratigraphiques et Paléontologiques pour servir à l'Histoire de la Période Tertiaire dans le Bassin du Rhone. 8vo. Paris, 1875-1889 ; and Depéret, Description Géol. du Bassin Tertiaire du Roussillon. *Ann. Sc. Géol.*, vol. xvii. 1885. The beds with *Potamides Basteroti* in the above table are sometimes classed with the Astian.

division with estuarine shells, such as *Potamides, Melanopsis,* and *Congeria.* The total thickness of the Plaisancian may reach as much as 200 or 250 metres.

In the neighbourhood of Montpellier, where I had an opportunity of examining the beds, the lower portion of this group consists of sands with thick banks of Oysters (*Ostrea cucullata*), and numerous bones of land and marine mammals. The abundance of bones of Sirenia (*Halitherium Serresii*) is very striking. Overlying the marine sands are sandy marls with brackish-water shells, as is usually the case in the south of France.*

On examining the Plaisancian fauna of the south of France, one is at once struck by the great difference of the mollusca from the north European assemblage, though the strata are apparently of the same age. To attempt any comparison between them is useless, the conditions and climate under which they respectively lived were so different. It is interesting, however, to notice that the temperature of the Mediterranean during the Plaisancian period seems to have been nearly as much above that of the existing Mediterranean, as the temperature of the Coralline Crag sea was above that of the seas that now wash the English coasts. The isotherms were probably as far apart then as now, but each was considerably south of its present position.

The Plaisancian deposits of Montpellier have yielded a considerable number of land mammals, of which Dr. Viguier has supplied a list of 15 species. The corresponding strata in the north of Europe, unfortunately have furnished very few of which the true horizon can be fixed. We have only the derivative fossils at the base of the Red Crag for purposes of comparison. A mastodon, a tapir, and a rhinoceros are probably common to Montpellier and Suffolk, the other mammals seem to be different. Here again no exact correlation is possible at present.

As we travel eastward, both the Plaisancian and the Astian become thoroughly marine, changing to strata of the Sub-Apennine type as we enter Italy. It is not, however, till the eastern side of the Gulf of Genoa is reached that the Pliocene strata expand into the wide thick sheet, lying between the Apennines and the sea, which led to the adoption of the term "Sub-Apennine" for the whole group.

Sub-Apennine strata cover enormous areas in Italy and Sicily, rising into low hills on each side of the Apennine chain. They have been little affected by the disturbance associated with the formation of these mountains. The Pliocene deposits sometimes rest conformably on, and pass down into, the Miocene; more commonly they abut against the disturbed rocks of the Apennines.

In Piedmont Tertiary rocks are largely developed, and as the relations of the deposits have recently been carefully worked out

* Viguier, Pliocène de Montpellier. *Comptes Rendus,* vol. cvi., p. 14,263. (1888.) *Bull. Soc. Géol. France,* ser. 3, vol. xvii., p. 379. (1889.)

by Prof. Sacco, this area may be taken as showing the character of the deposits in northern Italy. In his latest publications Prof. Sacco divides the Pliocene series thus* :—

		Metres.
Villafranchian (Villafranchiano)	Marls, clays, sands, and gravels. Fluvio-lacustrine	—
Fossanian (Fossaniano)	Marls, sand, and gravels. Littoral or estuarine	200
Astian (Astiano)	Marine sands, with beds of Oysters	
Plaisancian (Piacentino)	Marls and clays, full of marine fossils	100
Messinian (Messiniano).	Sandy marls, sometimes clayey, with seams of gypsum, limestone, and marine fossils. Alternating brackish-water and marine	200

There is a gradual passage between each of the divisions, and the lowest, the Messinian, rests conformably on, and passes down into the Tortonian (Miocene).

A like succession has been made out in Liguria by C. Mayer, and a similar series of changes, from the brackish-water Messinian to the deep-water Plaisancian, then to shoal-water Astian, becoming littoral at the top and passing into freshwater deposits variously named Arnusian, Villafrancian, &c., seems to have taken place throughout great part of Italy. In Sicily the Messinian division, or "Zanclean" as it was named by Prof. Seguenza, has apparently become more marine, though great part of it is unfossiliferous. Until, however, the detailed work of the Italian Geological Survey is more advanced, a good deal of the correlation of the minor divisions must be treated as provisional, for the mass of the deposits is great, and their thickness and lithological character vary considerably according to the proximity to the Apennines. In Tuscany there is still great uncertainty as to the exact relations of the celebrated lacustrine deposits of the Upper Val d'Arno with the marine Sub-Apennine Strata, only a few miles away. This will be again alluded to further on.

The lowest of the stages of the Italian Pliocene contains a molluscan fauna so unlike that of the Mediterranean, and having so large a proportion of extinct species—about 83 per cent.—that, as already observed, it is evidently older than any Pliocene deposit found in England. It probably represents the interval between the Bolderian and Diestian formations of Belgium.

From one third to nearly half the Plaisancian mollusca belong to living forms. There is a gradual change upwards, and a nearer approach to the existing fauna of the Mediterranean, till in Sicily we reach a stage, higher than the Astian, named "Sicilian" by Prof. Seguenza. This latest stage contains a fauna scarcely differing from that now found in the adjoining seas, except that among the fossils are a few northern forms,

* *See Bull. Soc. Belge de Géologie*, vol. iii., pp. 12–28. (1889), &c.

such as *Buccinum undatum* and *Cyprina islandica*, which no longer inhabit the Mediterranean. According to the definition ordinarily accepted in northern Europe, this stage would be called Pleistocene, not Pliocene.

In northern Italy this highest, or Sicilian, division has not been recognised, at least as a marine deposit. The elevation of such recent marine strata in Sicily and in Calabria appears to be connected with the formation of Mount Etna. So much has been said about the appearance of certain northern forms in the Italian Pliocene strata, that while in Italy I especially inquired of Prof. De Stefani whether any of them occurred in Tuscany. He had not seen one species, for these northern forms appear to be almost entirely confined to the Sicilian stage, or Pleistocene. In more than one museum in Tuscany I observed specimens incorrectly labelled *Tellina balthica*. They did not belong, however, to that species, but apparently to a form like the common Crag *Tellina obliqua*, though considerably smaller. Only two northern forms are included in Messrs. Ponzi and Meli's list from Monte Mario, near Rome.* This list contains 153 species, of which 30 are extinct, or about the same proportion as in the Upper Red Crag, with which the deposit may be correlated.

When the Coralline Crag fauna is compared with that of the Mediterranean region, it is with the existing Mediterranean species, not with the Pliocene ones, that we find the greatest resemblance. One cannot help being struck with the number of common Coralline Crag shells, or at any rate of mollusca closely allied to those of the Coralline Crag, that can be picked up during a stroll on the shore, or found in the fish-markets at Naples. Still the faunas are not identical, and the Coralline Crag mollusca have not simply migrated southward, as the climate changed. The Mediterranean and the Celtic regions are characterized by numerous forms which have survived for long periods in the one area, but are never found in the other. The climatic changes have not sufficed to destroy the evidence that the two regions have for many ages belonged to distinct subprovinces, probably seldom with any very direct communication.

The free-roaming sharks point more clearly than the mollusca to the similarity of the present temperature of the Mediterranean to that found in our latitudes in early Pliocene times. The sharks commonly exposed in the fish-market at Florence during my visit were *Carcharias*, *Carcharodon*, *Notidanus*, and *Oxyrhina*—the last three common genera of our Nodule Bed.

There was one point which in visiting the Mediterranean region I was anxious if possible to settle. Could we anywhere match the peculiar calcareous deposit which forms the Coralline Crag? Contemporaneous cementing of the sea-bottom into a hard mass—one of the most interesting peculiarities of the

* *Mem. R. Accad. dei Lincei*, ser. 4, vol. iii., p. 672. (1887.)

Coralline Crag—has often been observed. It seems to be a common characteristic of warm seas. But none of the specimens of sea-bottoms preserved at the Naples Zoological Station at all corresponded in lithological character with the calcareous Coralline Crag, and I was informed that no deposit of that kind had been found within the area over which they dredge. Even in the thick mass of Sub-Apennine strata in Tuscany, the only approach to a calcareous deposit of this kind yet noticed, occurs at one spot, where under the guidance of Dr. Canavari some calcareous sand full of Bryozoa was observed. The other calcareous Pliocene strata, such as the *Amphistegina*-limestone are of a totally different character. The recent deposits of this part of the Mediterranean, and also the Pliocene strata, consist largely of inorganic sediments. To match the Coralline Crag we should apparently need to go much further from the land.

Turning next to the land and freshwater deposits, we have seen that none of those in Britain belong to the older series, the only strata not of marine origin representing the close of the Newer Pliocene. There are, however, a number of derivative bones of land-mammals of Older Pliocene age in the Nodule Bed at the base of the Red Crag, and the higher marine divisions, especially the Norwich Crag, have yielded a good many contemporaneous species. We thus find in the British Pliocene strata three distinct mammalian faunas—that of the Nodule Bed (the base of the Lower Pliocene?)—that of the Norwich Crag (the middle of the Upper Pliocene)—and that contained in the Cromer Forest-bed (top of Upper Pliocene). Of land and freshwater mollusca a few are found in the Coralline Crag and Walton Crag; they are common in the upper Crags; and are well-represented in the Forest-bed. Other land and freshwater animals, such as fish and beetles, are confined to the Forest-bed. Of the Pliocene birds we as yet know too little for any comparison to be possible. Plants are entirely confined to the Forest-bed.

Thus there is still a great deficiency of evidence on which to correlate the minor divisions, for the most complete British Pliocene land fauna and flora is but poorly represented in France. The principal French mammaliferous zones, on the other hand, seem practically unknown in Britain. No assistance can be derived from Belgium or Normandy, for their Pliocene strata yield no land mammals, except the few indeterminable fragments recently found at Antwerp. The nearest Pliocene land or freshwater deposit met with in France, is 4° south of the Cromer Forest-bed, its principal English equivalent, and 2° south of Dewlish.

Some mammaliferous gravels of Upper Pliocene age occur at Saint-Prest, near Chartres. They have yielded *Elephas meridionalis*, *Rhinoceros Mercki* (*R. megarhinus?*), *Hippopotamus major*, *Trogontherium Cuvieri*, and *Cervus carnutorum*.

This fauna, as far as it goes, might belong either to the Norwich Crag or to the Forest-bed; but the absence of the Mastodon is in favour of its reference to the newer division. *Cervus carnutorum* is confined in England to the Chillesford Beds, though we might expect to discover this and the other extinct forms in newer and newer deposits as we travel further south, beyond the influence of the extreme cold of the Glacial period. The correlation of the gravel at Saint-Prest with the Cromer Forest-bed is generally accepted.

Certain lignitic deposits at Dürnten and Utznach, in Switzerland, are sometimes correlated with the Cromer Forest-bed; but there is nothing in the fauna or flora to justify this allocation, for the species are like those of the British Pleistocene strata. The most probable correlation is with some of the British interglacial deposits, such as those of Holderness.

In the volcanic region of Auvergne we find various fluviatile deposits or tuffs undoubtedly of Pliocene age. They are, however, so intricately interbedded with lava-flows that it is difficult to make out the stratigraphical relations of the different masses. The principal locality where the mammalian remains occur is at Mont Perrier, a steep escarpment facing a tributary of the river Allier, near Issoire. Here an old Pliocene lake-bed or alluvium has been overflowed by lava, which has served partially to protect the underlying strata, though they are now eroded into the precipitous cliffs and slopes which surround the gently-inclined Plateau de Pardines. The preservation of the Pliocene Alluvium in Auvergne is due to a cause somewhat similar to that which has led to the preservation of the Cromer Forest-bed; in the one case a sheet of basalt protected the soft strata, in the other it was a sheet of Boulder Clay.

At Mont Perrier, which forms the southern edge of the Plateau de Pardines, the Pliocene deposits are wasting rapidly under the influence of the rain, and bones are often washed out. The section of the strata is fine, though much of it is so steep as to be almost inaccessible, for no footing can be obtained in these crumbling sands. The lower part of the section is as follows* :—

	Metres.
Red conglomerate, with large blocks of trachyte and basalt; forming the base of the beds which contain the celebrated fauna of Perrier	2
Shaly clays, with fish, lignite, and pyrites	7 or 8
Conglomerate of large rounded quartz-pebbles, with some fragments of basalt	2
Lacustrine marl (Miocene).	

This section was measured in the road-cutting above the village. The higher deposits are more sandy.

The fossils of Mont Perrier, consisting almost entirely of mammalia, are sometimes considered to represent two periods—

* Potier, *Bull. Soc. Géol. France*, ser. 3, vol. vii., p. 937. (1879.)

the Middle Pliocene and the Upper Pliocene. Dr. Ch. Depéret, however, treats them as belonging to one zone, and adopts a classification similar to that used for the marine deposits. He classes the fauna of Mont Perrier, and that of certain neighbouring deposits, evidently of the same age, as the first Upper Pliocene fauna, correlating it with that of the Val d'Arno and with the Norwich Crag. The fauna of Montpellier he considers to be somewhat older, and to belong to the true Middle Pliocene. This classification accords well with that used for the British Pliocene deposits, for though there is a great resemblance between the Auvergne fauna and that of the Nodule Bed, yet when we take into account the difference of latitude, it is more with the Norwich Crag that we ought, I think, to compare it. At present we must await the discovery of more mammalia in the English Crag. The only point that seems quite clear, is that the strata of Pardines must be somewhat older than those at Saint-Prest and Cromer, and newer than the Astian at Montpellier, with its apes and hipparions. Among the fossils at Pardines we find mastodon and tapir, but the occurrence of elephant is doubtful. This would seem to indicate that the strata of the Val d'Arno, containing *Elephas meridionalis* and *Equus Stenonis*, may include a somewhat higher zone, approaching more nearly to the Cromer Forest-bed.

The occurrence of freshwater deposits of Pliocene age, scattered over a considerable portion of France, seems to indicate that this period was essentially a continental one, and that if it were not for the difference of latitude we might expect to find a close approach to the fauna of England. A number of the free-roaming mammals are common to England and France, but it is curious that out of about 15 species of deer from the Cromer Forest-bed, only three or four have also been discovered in France, and two of these range as far as the Val d'Arno. The Forest-bed contains more species of deer than any other deposit yet known.

The only freshwater strata in southern Europe that can with any advantage be compared with the British Pliocene are those of the Upper Val d'Arno. A short distance above Florence the valley of the Arno narrows into a rocky gorge, beyond which the marine Sub-Apennine strata do not pass. Above this gorge the valley expands into a wide plain, known as the Val d'Arno Superiore, stretching in a south-easterly direction nearly as far as Arezzo, and having a width of several miles. If we stand on one of the spurs of the Apennines and look down on this plain, we see it to end abruptly against the hills on the further side, its lake-like appearance and conspicuous shore-line being very marked. When we approach nearer, or descend to it, we find the plain to be cut up into separate flat-topped blocks, or ploughed into by narrow gorges and cañons, so that the district has a singular resemblance, on a small scale, to the cañon region of the Colorado. The gorges are often one or two hundred feet deep, and so steep that no vegetation can grow on their sides.

Thus many miles of continuous deep sections of the old lacustrine deposits have been laid bare. Through the kindness of Dr. Ristori, who has made a special study of, and lives in the middle of the district, I had an opportunity of examining the upper Val d'Arno under his guidance.

Though a large number of bones have been discovered in the lacustrine strata of the Val d'Arno, fossiliferous localities are not numerous, and shells and plants only occur in certain localities. To judge by the number of specimens in the various museums, scarcely so many bones have been found as in the Cromer Forest-bed, notwithstanding the enormously greater extent of the sections. In all probability the fauna is still only imperfectly known.

The oldest Pliocene strata in the upper Val d'Arno, seem to be the lignite beds and associated leaf-beds, which outcrop at the margin of the basin near Castelnuovo and Gaville. The lignite is extensively mined, being about 100 feet thick. It was unfortunately impossible to examine the mines so thoroughly as I could wish, for the lignite had caught fire a few days before my visit, and was still burning. However, the large open quarries showed excellent sections of the lignite as well as of the underlying laminated blue clays, full of leaves. Some distance below these clays teeth of Tapir are found, but no other mammals have yet been discovered on this horizon.

The plants of the lignite and associated clays of the Val d'Arno have recently been described by Dr. Ristori,* who records no less than 113 species, nearly all of them deciduous trees, apparently of extinct species. The number of forms no longer living, suggests that in the plant-beds we may have deposits somewhat older than the mammaliferous strata of the rest of the basin, though they are generally classed together. An enormous preponderance of extinct forms among the plants is scarcely what we should expect in Newer Pliocene strata.

The mammalia of the Val d'Arno are of great interest to the English geologist, for among them occur abundantly certain well-known species of the Forest-bed.† *Elephas meridionalis*, *Rhinoceros etruscus*, and *Hippopotamus major* are common in both districts and two of the deer and a horse are also found in both. The other species of the Val d'Arno mammals, such as the tapir and mastodons, perhaps point to a slightly older date, perhaps merely to a warmer climate. The general facies of the whole mammalian fauna is similar to that of the Forest-bed, except that the difference of latitude gives a more southern character to the assemblage, and allows two species of apes to appear. The Alps evidently formed no barrier to the migration of the Pliocene mammalia, and the narrow belt of low ground between the Maritime Alps and the sea probably sufficed to

* *Atti Soc. Toscana Sci. Naturali*, vol. vii., fasc. 1. (1885.)

† C. J. Forsyth Major, On the Mammalian Fauna of the Val d'Arno. *Quart. Journ. Geol. Soc.*, vol. xli., p. 1. (1885.)

allow of free communication between Italy and France, and probably therefore with England.

The land and freshwater mollusca of the Val d'Arno agree with the plants in their want of similarity with living forms. Eleven species are recorded by Prof. De Stefani, all being extinct, and none of them corresponding with British Pliocene fossils.* In fact half a dozen widely distributed living species, and one extinct snail (*Helix suttonensis*) are the sole links that connect the Pliocene land and freshwater mollusca of England with either the living or extinct species of Italy. It would seem that the route through the Riviera, so easily passed by the migrating mammals, was impracticable for freshwater mollusca, for the small streams are all at right angles to the path. For this group the western Alps would probably form a complete barrier.

The occurrence of the freshwater *Lithoglyphus fuscus* of the Danube fossil in England, and the absence of all the characteristic Pliocene freshwater shells of Italy, lends further countenance to the suggestion that the freshwater mollusca may have followed a different line from that pursued by the mammalia, and that they may have crossed the Alps at the low divides which separate some of the head-waters of the Rhine and Elbe from the Danube. Any new species of freshwater shells which may yet be discovered in our Pliocene beds ought perhaps to be found also in Austria rather than in the Val d'Arno, but at present the Upper Pliocene fauna of central Europe is imperfectly known. The Pliocene strata of the Vienna basin consist of *Congeria*-beds, with Lower Pliocene mammals, such as *Mastodon*, *Deinotherium*, *Acerotherium*, and *Hipparion* A somewhat similar mammalian fauna occurs at Epplesheim, in the Mainz basin, in sand and gravel with lignite; but in both districts the later stages of the period seem to be unrepresented.

Since these pages were in type, advance sheets have been received, thanks to Dr. Lorié and M. Van den Broeck, of a new paper on some deep borings at Amsterdam.† One of these borings, that at Diemerbrug, descends to a depth of 1,096 feet below the sea-level, but it is doubtful whether any portion of this great thickness of newer Tertiary deposits is so old as the Diestian. Dr. Lorié was at one time inclined to refer the strata between 265 and 320 metres (867 to 1,047 feet) to the Diestian series; his list of mollusca obtained between these depths is therefore quoted :—

Calyptræa sinensis.
Chemnitzia densecostata.
—— elegantissima.
—— indistincta.
Fusus scalariformis.
Natica Alderi.
Pleurotoma turricula.
Ringicula ventricosa.
Rissoa reticulata.
Turritella terebra.
Anomia ephippium.
Cardita orbicularis.
Cardium edule.
—— subturgidum.
Corbula contracta.

* Molluschi Continentali Pliocenici d'Italia. *Atti Soc. Tosc. Sci. Nat.*, 1876–84.

† Lorié, Contribution à la Géologie des Pays-Bas. Part IV.—Les deux derniers Forages d'Amsterdam. *Bull. Soc. Belge Géol.*, vol. iii., pp. 409–449. (1890.)

Corbula gibba.
Dosinia lincta.
Leda lanceolata.
—— myalis.
Lucina arcuata.
Mactra solida.
Mya Binghami.
Mytilus edulis.
Nucula Cobboldiæ.
—— lævigata.
Pecten Gerardi.
—— opercularis.
—— ventilabrum.
Saxicava rugosa.
Tellina prætenuis.
Venus ovata.

In favour of the Diestian age of the lower strata in this well Dr. Lorié mentions five species of mollusca as characteristically Lower Pliocene; all of them, however, are either living British forms or have been found in the Red Crag. On the other hand, as Dr. Lorié points out, there is the absence of many characteristic Diestian species, and the presence of several Arctic and upper Crag forms. The conclusion Dr. Lorié comes to is that the strata are probably of Scaldisian age, and to me the general character of the fauna appears like that of the Walton Crag, with the addition of certain northern species. Dr. Lorié brought forward as an argument against the Scaldisian age of the lower deposits, that the thickness of this division would be so much greater at Amsterdam than at Utrecht. Amsterdam, however, is on the shores of the Zuyder Zee, and in the middle of the great delta region which we have already shown to have formed a subsiding area since early Pliocene times—it is here that we should expect the Pliocene deposits to reach their greatest development. Interesting evidence is adduced by Dr. Lorié in favour of a great subsidence of this district, for high up in the undoubted Scaldisian deposits at Diemerbrug, but still 750 feet below the sea, a seam was found containing land and freshwater shells (*Hydrobia similis*, *Zonites*, sp., *Succinea elegans*. *Clausilia pliocena*, and *Pupa muscorum*).

One reason why especial attention is drawn to this well is that it seems to yield evidence of a cold area in the Pliocene sea; for if the lower deposits are as new as the Walton Crag, yet the fossils point to colder water than is evidenced in the British Red Crag; whilst if the sand at Amsterdam corresponds with the Coralline Crag, the contrast is still greater. There is, however, no trace of deep-water deposits either at Amsterdam or Utrecht.

As a key to the correlation of the British and Continental Pliocene strata, the table (pp. 222, 223) has been drawn up. Any attempt to fix the exact limits of each division has purposely been avoided in it; for it must always be remembered that a change of physical conditions, or even a change in the fauna, may be far from occurring simultaneously in different countries.

British Pliocene Deposits

	England.
Pleistocene	Arctic Freshwater Bed (with *Salix polaris, Betula nana*, &c.).
Newer Pliocene (cold temperate).	Leda-myalis Bed (classed provisionally with the Pliocene).
	Forest-bed Series. { Upper Freshwater. / Estuarine. / Lower Freshwater. } Gravels with *Elephas meridionalis* at Dewlish.
	Weybourn Crag (and Chillesford Clay ?).
	Chillesford Crag.
	Norwich Crag and *Scrobicularia* Crag.
	Red Crag of Butley, &c.
	Walton Crag (lower Red Crag).
Older Pliocene (warm temperate).	St. Erth Beds.
	Coralline Crag and Lenham Beds.
	Box stones and phosphate beds at the base of the Red and Coralline Crags (with *remanié* early Pliocene fossils).
	Wanting.
Miocene	Wanting.

AND THEIR FOREIGN EQUIVALENTS.

Belgium and Holland.	North and Central France.	South of France.	Italy and Sicily.
?	?	?	Sicilian (with recent marine mollusca).
			Villafrancian. (fluvio-lacustrine).
	Horizon of Saint-Prest, with *Elephas meridionalis*.	Arnusian.	passing into
			Fossanian. (littoral and estuarine).
	Horizon of Perrier, with *Mastodon arvernensis*, *Tapirus*, &c.		passing into
		Astian. Freshwater beds with *Semnopithecus* and *Mastodon arvernensis*.	Astian. (marine, with 20 °/₀ extinct mollusca).
Sables à *Trophon antiquus*, or Scaldisian.	*Nassa*-beds of Saint-Martin d'Aubigny and *Terebratula*-beds of Saint-Georges-de-Bohon and Gourbesville.		passing into
Sables à *Isocardia Cor*, or Diestian.	Diestian sands (unfossiliferous).	Plaisancian. Estuarine beds with *Potamides Basteroti*. Marine beds with *Nassa semistriata*.	Plaisancian or Piacentino (marine).
			passing into
Wanting.		Messinian. Brackish-water deposits with *Congeria*.	Messinian, or Zanclean (brackish-water or marine, with 83 °/₀ extinct mollusca).
			passing into
Anversian and Bolderian.	"Falun à Bryozoaires" of Saint-Eny.	Tortonian.	Tortonian.

Lacustrine strata of the Val d'Arno.

APPENDIX I.

TABLES OF FOSSILS.

Section I.—Fauna and Flora of the Land, Lakes, and Rivers.

Table I.—Vertebrata.

(By E. T. Newton, F.G.S., F.Z.S.)

	Nodule Bed.	Coralline Crag.	Norwich Crag.	Weybourn Crag.	Forest-bed.	Pleistocene.	Living.	Extinct.	
Mammalia.									
(Carnivora.)									
Felis pardoides, *Owen*	×	..	..	..	..	..	..	×	
Machærodus	..	..	?	..	×	×	..	×	
Canis lupus, *Linn.*	×	..	..	..	×	×	×		
—— vulpes, *Linn.*	..	..	..	..	×	×	×	..	Also Red Crag ?
——? primigenius, *Lank.*	×	..	..	..	..	..	..	×	
Pterodon	×	..	..	..	..	..	..	×	
Hyæna crocuta, *Erxl.*	..	..	..	..	×	×	×		
—— striata, *Zimm.*	×	..	..	..	..	..	×		
Hyænarctos	×	..	..	..	..	..	..	×	
Ailurus anglicus, *Dawk.*	×	..	..	..	..	..	..	×	
Ursus arvernensis ? *Cr. & Job.*	×	..	..	..	..	..	..	×	
—— horribilis, *Ord.*	..	..	..	..	?	×	×	..	U. ferox.
—— spelæus, *Blum.*	..	..	..	..	×	×	..	×	
Mustela martes, *Linn.*	..	..	..	..	×	×	×		
—— putorius, *Linn.*	..	?	..	..	..	×	×	..	Cor. Crag, Orford ?
Gulo luscus, *Linn.*	..	..	..	..	×	×	×		
Lutra vulgaris, *Erxl.*	..	..	?	..	×	×	×		
—— dubia, *Blainv.*	×	..	..	..	..	..	..	×	
—— Reevli, *Newt.*	..	..	×	..	..	..	..	×	
(Ungulata.)									
Bison Bonasus, *Linn.*	..	..	..	..	×	×	×		
Ovibos moschatus, *Zimm.*	..	..	..	..	×	×	×		
Caprovis Savinii, *Newt.*	..	..	..	..	×	..	..	×	
Antilope ?	×								
Gazella anglica, *Newt.*	..	..	×	..	..	..	..	×	
Capreolus caprea, *Gray*	..	..	..	..	?	×	×		
Alces latifrons, *Johnson*	..	..	..	..	×	..	..	×	C. bovides, MS.

TABLE I.—*continued.*

	Nodule Bed.	Coralline Crag.	Norwich Crag.	Weybourn Crag.	Forest-bed.	Pleistocene.	Living.	Extinct.	
Cervus ardeus, *Cr. & Job.*	..	..	×	..	..	..	..	×	
—— carnutorum, *Laug.*	..	..	×	..	..	..	..	×	
—— Dawkinsi, *Newt.*	..	..	..	..	×	..	..	×	
—— dicranoceros, *Nesti*	×	..	..	..	..	..	..	×	Cervulus.
—— elaphus, *Linn.*	..	..	..	..	×	×	×		
—— Etueriarum, *Cr. & Job.*	..	..	..	..	×	..	..	×	
—— Falconeri, *Dawk.*	×	..	×	..	..	..	..	×	
—— Fitchii, *Gunn*	..	..	..	..	×	..	..	×	C. Gunnii.
—— Polignacus, *Robert*	..	..	..	..	×	..	..	×	
—— rectus, *Newt.*	..	..	..	..	×	..	..	×	
—— Savinii, *Dawk.*	..	..	..	..	×	..	..	×	
—— Sedgwickii, *Falc.*	..	..	..	..	×	..	..	×	
—— suttonensis, *Dawk.*	×	..	×	..	..	..	..	×	
—— tetraceros, *Mackie*	..	..	..	..	×	..	..	×	
—— verticornis, *Dawk.*	×	..	..	..	×	..	..	×	
Xiphodon platyceps, *Flower*	×	..	..	..	..	..	..	×	
Hippopotamus amphibius, *Linn.*	..	..	..	..	×	×	×		
Sus antiquus ? *Kaup*	×	..	..	..	..	..	..	×	or S. erymanthius.
—— palæochœrus, *Kaup*	×	..	..	..	..	..	..	×	
—— scrofa, *Linn.*	..	..	..	..	×	×	×		
Equus caballus, *Linn.*	?	..	..	..	×	×	×	..	E. plicidens ?
—— Stenonis, *Cocchi*	..	..	×	..	×	..	..	×	
Hipparion gracile, *Kaup*	×	..	..	..	..	..	..	×	
Rhinoceros incisivus, *Kaup*	×	..	..	..	..	..	..	×	
—— Schleiermacheri, *Kaup*	×	..	..	..	..	..	..	×	Also beneath the Coralline Crag.
—— etruscus, *Falc.*	..	..	..	..	×	..	..	×	
—— megarhinus, *Christol*	..	..	..	..	?	×	..	×	
Tapirus arvernensis, *Dev. & Bou.*	×	..	..	..	..	..	..	×	T. priscus of Owen.
Hyracotherium leporinum, *Owen*	×	..	..	..	..	..	..	×	London Clay.
Coryphodon	×	..	..	..	..	..	..	×	Eocene.
Mastodon arvernensis, *Cr. & Job.*	×	..	×	..	..	..	..	×	
—— Borsoni, *Hays*	×	..	..	..	..	..	..	×	
—— longirostris, *Kaup*	×	..	..	..	..	..	..	×	Also beneath the Coralline Crag.
Elephas antiquus, *Falc.*	..	..	×	..	×	×	..	×	
—— meridionalis, *Nesti*	×	..	?	..	×	..	..	×	Also at Dewlish.
—— primigenius, *Blumb.*	..	..	..	..	?	×	..	×	Variety only in the Forest-bed.
(Rodentia.)									
Arvicola amphibius, *Linn.*	..	..	..	..	?	×	×	..	Gen. Microtus.

TABLE I.—*continued.*

	Nodule Bed.	Coralline Crag.	Norwich Crag.	Weybourn Crag.	Forest-bed.	Pleistocene.	Living.	Extinct.	
Arvicola arvalis, *Pallas*	..	..	..	..	×	×	×	..	Gen. Microtus.
——— glareolus, *Schreb.*	..	..	..	..	×	×	×	..	„
——— gregalis, *Pallas*	..	..	..	..	×	..	×	..	„
——— intermedius, *Newt.*	..	..	×	×	×	..	..	×	„
Sciurus vulgaris? *Linn.*	..	..	..	..	×	..	×		
Mus sylvaticus, *Linn.*	..	..	..	..	×	..	×		
Castor fiber, *Linn.*	×	..	..	..	×	×	×	..	C. europæus, *Owen.*
——— veterior, *Lank.*	×	..	..	..	..	..	..	×	
Trogontherium Cuvieri, *Owen*	..	..	×	..	×	..	..	×	
——————— minus, *Newt.*	×	..	×	..	..	..	..	×	
(Insectivora.)									
Talpa europæa, *Linn.*	..	..	..	..	×	×	×		
Sorex vulgaris, *Linn.*	..	..	..	..	×	..	×		
——— pygmæus, *Pallas*	..	..	..	..	×	..	×		
Myogale moschata, *Linn.*	..	..	..	..	×	..	×		
AVES.									
Bubo ignavus, *Forster*	..	..	..	..	×	..	×	..	B. maximus.
Phalacrocorax carbo, *Linn.*	..	..	..	..	×	..	×		
Anser	..	..	..	..	×	..	?		
Anas	..	..	..	..	×	..	?		
Spatula clypeata, *Linn.*	..	..	..	..	×	..	×		
Uria troile, *Linn.*	..	..	×	..	..	..	×	..	Also Aldeby.
Mergulus	..	..	×	..	..	..	×	..	Yarn Hill.
Diomedea	..	×	..	..	..	×	×	..	Also Red Crag.
REPTILIA.									
Tropidonotus natrix, *Linn.*	..	..	..	..	×	..	×		
Pelias berus, *Linn.*	..	..	..	..	×	..	×		
AMPHIBIA.									
Rana temporaria, *Linn.*	..	..	..	..	×	..	×		
—— esculenta, *Linn.*	..	..	..	..	×	..	×		
Bufo	..	..	..	..	×	..	×		
Triton cristatus, *Laur.*	..	..	..	..	×	..	×		
PISCES.									
Perca fluviatilis, *Linn.*	..	..	..	..	×	×	×		
Acerina vulgaris? *Cuv.*	..	..	..	..	×	..	×		
Esox lucius, *Linn.*	..	..	..	..	×	×	×		
Barbus vulgaris? *Flem.*	..	..	..	..	×	..	×		

TABLE I.—*continued.*

	Nodule Bed.	Coralline Crag.	Norwich Crag.	Weybourn Crag.	Forest-bed.	Pleistocene.	Living.	Extinct.	
Leuciscus rutilus, *Linn.*	..	..	..	..	×	..	×		
——— cephalus ? *Linn.*	..	..	..	..	×	..	×		
——— erythrophthalmus, *Linn.*	..	..	..	..	×	..	×		
Tinca vulgaris, *Cuv.*	..	..	..	..	×	..	×		
Abramis brama, *Linn.*	..	..	..	..	×	..	×		
Acipenser	×	..	×	..	×	..	×		

TABLE II.—LAND AND FRESHWATER MOLLUSCA.

The authorities for the different horizons are: Coralline Crag, S. V. Wood; Red Crag of Walton, S. V. Wood and A. and R. Bell; Red Crag of Butley, &c., S. V. Wood, Prestwich, and A. and R. Bell; Norwich and Chillesford Crags, S. V. Wood, A. and R. Bell, and Prestwich; Weybourn Crag and Forest-bed, Clement Reid.

	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	
GASTEROPODA.								
Ancylus fluviatilis, *Müll*	..	..	..	..	..	..	?	Forest-bed (A. Bell).
——— lacustris, *Linn.*	..	..	×	..	..	..	×	Velletia lingulata, *Sandb.*
Bulimus, see Zua.								
Bythinia Leachii, *Shep.*	..	..	..	..	..	..	×	
——— tentaculata, *Linn.*	..	..	..	×	..	..	×	
Carychium minimum, *Müll.*	..	..	..	×	..	..	×	C. ovatum, *Sandb.*
Clausilia perversa ? *Müll.*	..	..	..	..	..	..	×	
——— pliocena, *S. Wood*	×	..	..	..	..	..	..	Extinct.
Helix arbustorum, *Linn.*	..	..	..	×	×	×	×	
——— fulva, *Müll.*	..	..	..	..	..	..	×	
——— hispida, *Linn.*	..	..	×	×	×	×	×	
——— incarnata, *Müll.*	..	×	..	..	..	..	..	Southern.
——— lactea, *Müll.*	..	×	..	..	..	..	..	Southern.
——— lens, *Fér.*	..	×	..	..	..	..	..	Southern.
——— nemoralis, *Linn.*	..	..	..	..	..	..	×	H. Haesendoncki, *Ny.*
——— pulchella, *Müll.*	..	..	×	×	..	..	×	H. tenuilimbata, *Sdb.*
——— pygmæa, *Drap.*	..	..	..	..	..	..	×	

TABLE II.—*continued.*

—	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	—
Helix rysa, *S. Wood*	..	×	×	..	..	..	..	H. rufescens, var.? (G. J.).
—— suttonensis, *S. Wood*	×	..	..	..	..	..	..	Extinct.
Hydrobia marginata, *Mich.*	..	..	..	..	..	..	×	Belgrandia nana? *Sandb.*
—— Steinii, *v. Martens*	..	..	..	..	..	..	×	Living, Sweden and near Berlin.
Limax modioliformis, *Sandb.*	..	..	..	..	..	..	×	Extinct.
—— Sowerbyi, *Fér.*	..	..	..	..	..	..	×	
Limnæa auricularia, *Linn.*	..	..	..	×				
—— Holbollii? *Möll.*	..	..	×	×	..	..	..	Arctic?
—— palustris, *Müll.*	..	..	×	×	×	×	×	L. labio, *Sandb.*
—— limosa, *Linn.*	..	..	×	×	×	..	×	L. peregra, *Müll.*
—— Pingelii? *Möll.*	..	..	..	×	..	..	..	Arctic?
—— stagnalis, *Linn.*	..	..	?	..	..	..	×	
—— truncatula, *Müll.*	..	..	×	×	×	..	×	
Lithoglyphus fuscus, *Pfr.*	..	..	..	..	..	×	..	Living in the Danube.
Nematura runtoniana, *Sandb.*	..	..	..	..	..	..	×	Extinct.
Paludina gibba, *Sandb.*	..	..	..	..	..	..	×	P. contecta of "Crag Mollusca."
—— ? glacialis, *S. Wood*	..	..	..	..	×	×	×	Extinct.
—— media, *Woodw.*	..	×	×	×	×	..	×	Extinct.
—— vivipara, *Linn.*	..	..	..	..	×	×	×	
—— sp. nov.?	..	..	..	..	..	×	×	Extinct.
Physa fontinalis, *Linn.*	..	..	..	..	..	..	×	
Planorbis albus, *Müll.*	..	..	×	..	..	×	×	
—— carinatus, *Müll.*	..	..	..	..	..	..	×	
—— complanatus, *Linn.*	..	..	×	×	×	..	×	
—— contortus, *Linn.*	..	..	..	..	..	..	×	
—— corneus, *Linn.*	..	..	×	×	..	×	×	P. clathratus, *Sandb.*
—— crista, *Linn.*	..	..	..	..	..	..	×	P. nautileus.
—— nitidus, *Müll.*	..	..	..	..	..	..	×	
—— spirorbis, *Linn.*	..	..	×	×	..	..	×	
—— vortex, *Linn.*	..	..	..	..	..	..	×	
Pupa edentula, *Drap.*	..	..	..	×				
—— muscorum, *Linn.*	..	..	×	×	..	..	×	P. marginata, *Drap.*
—— umbilicata, Drap.	..	..	..	×	..	..	..	Yarn Hill (R. E. Leach).
Succinea oblonga, *Drap.*	..	..	..	×	..	×	×	
—— putris, *Linn.*	..	..	×	×	..	..	×	
Valvata cristata, *Müll.*	..	..	..	×	..	..	×	
—— fluviatilis, *Colb.*	..	..	..	..	..	..	×	Living, Belgium and Germany.

TABLE II.—*continued.*

	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	
Valvata piscinalis, *Müll.*	..	..	..	×	×	..	×	
——— var. antiqua	..	..	..	..	..	..	×	
——— depressed var.	..	..	..	..	..	..	×	
Vertigo antivertigo, *Drap.*	..	..	..	..	..	..	×	
Vitrina pellucida, *Müll.*	..	..	..	..	..	..	×	
Zua subcylindrica, *Linn.*	..	..	×	..	..	..	×	Bulimus lubricus, *Müll.*
Zonites, sp.	..	..	..	..	..	..	×	
LAMELLIBRANCHIATA.								
Anodonta cygnea, *Linn.*	..	..	..	..	..	..	×	
——— var. anatina	..	..	..	..	..	..	×	
Corbicula fluminalis, *Müll.*	..	×	×	×	×	×	×	Extinct in Britain.
Cyclas, see Sphærium.								
Pisidium amnicum, *Müll.*	..	..	..	×	×	×	×	
——— astartoides, *Sandb.*	..	..	×	×	..	..	×	Extinct.
——— casertanum, *Poli*	..	..	..	..	..	..	×	
——— henslowianum, *Shep.*	..	..	..	..	..	..	×	
——— nitidum, *Jenyns*	..	..	..	..	..	..	×	
——— pulchellum, *Jenyns*	..	..	..	..	..	..	×	
——— pusillum, *Gmel.*	..	..	..	..	..	..	×	
——— roseum, *Scholtz*	..	..	..	..	..	..	×	
Sphærium corneum, *Linn.*	..	..	..	×	×	..	×	
——— ovale, *Fér.*	..	..	..	..	..	..	×	
——— rivicola, *Leach*	..	..	..	..	..	..	×	
Unio littoralis, *Lam.*	..	..	..	..	..	..	?	Forest-bed (A. Bell), Southern.
——— pictorum, *Linn.*	..	..	..	?	..	×	×	

Pisidium astartoides has generally been considered to be a variety of *P. amnicum*, though at West Runton the two species are found side by side with the valves united, and among several hundred specimens of each no intermediate forms could be found. At present there is no agreement among conchologists as to the limits of the different species in the genus *Pisidium*, but nearly all the British forms seem to occur in the sandy portion of the bed at West Runton.

Figures of many of the Pliocene land and freshwater mollusca will be found in Plate V. of this work; in S. V. Wood's "Crag Mollusca"; and in Sandberger's "Ein Beitrag zur Kenntniss der unterpleistocänen Schichten Englands," *Palæontographica*, 1880.

TABLE III.—FRESHWATER OSTRACODA.

Authority:—Jones and Sherborn, Supp. Tertiary Entomostraca, Palæontographical Soc.

—	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	—
Candona candida, *Müll.*	..	..	..	..	..	..	×	
Cypridopsis obesa, *B. & R.*	..	..	..	..	..	..	×	
Cypris browniana, *Jones*	..	..	..	..	..	..	×	
—— gibba, *Ramdohr*	..	..	..	..	..	..	×	
—— reptans, *Baird*	..	..	..	..	..	..	×	
Cytheridea torosa, *Jones*	..	..	..	..	..	..	×	
Darwinula Stevensoni, *B. & R.*	..	..	..	..	..	..	×	
Potamocypris trigonalis, *Jones*	..	..	..	..	..	×	..	Δ brackish water genus.
—— —— var. lævis	..	..	..	×	..	..	..	
—— tuberculata, *Jones*	×	×	..	..	..	..	..	

TABLE IV.—COLEOPTERA OF THE CROMER FOREST-BED.

Donacia linearis. Recorded by A. and R. Bell.
——— sericea, Linn. Determined by C. O. Waterhouse.
Oiceptoma dispar. Recorded by A. and R. Bell.
Pterostichus madidus ? Fab. Determined by C. O. Waterhouse.
Numerous undetermined species.

TABLE V.—FLORA OF THE CROMER FOREST-BED.

(No determinable plants have yet been found in other British Pliocene strata.)

DICOTYLEDONS.

Thalictrum flavum, *Linn.* (Meadow Rue.) Common.
Ranunculus aquatilis, *Linn.* (Water Crowfoot.) Very common.
——— repens, *Linn.* (Buttercup.) Common.
Caltha palustris, *Linn.* (Marsh Marigold.) Mundesley.
Nuphar luteum, *Linn.* (Yellow Water-lily.) Very common.
[Nymphæa alba, *Linn.*]. King collection only—doubtful.
Viola palustris, *Linn.* (Marsh Violet.) Common.
Stellaria aquatica, *Scop.* (Water Chickweed.) Beeston only.
——— media ? *Linn.* (Chickweed.) Overstrand only.
Acer campestre, *Linn.* (Lesser Maple.) Abundant at Pakefield.
Prunus communis, *Huds.* (Sloe.) Rare.
Rubus fruticosus, *Linn.* (Blackberry.) Mundesley and Pakefield.
Poterium officinale, *Hook.* (Great Burnet.) Mundesley and Sidestrand.
Cratægus Oxyacantha, *Linn.* (Hawthorn.) Overstrand.
Hippuris vulgaris, *Linn.* (Marestail.) Very common.
Myriophyllum spicatum, *Linn.* (Water Milfoil.) Common.
Trapa natans, *Linn.* (Water Chesnut.) Sidestrand, Mundesley, Ostend, Pakefield.
Œnanthe Lachenalii, *Gmel.* Mundesley and Pakefield.

[Peucedanum palustre, *Moench.*] A wrong determination.
Heracleum Sphondylium, *Linn.* (Hogweed.) Pakefield.
Cornus sanguinea, *Linn.* (Cornel.) Happisburg and Pakefield.
Bidens tripartita, *Linn.* (Bur Marigold.) Mundesley and Pakefield.
Carduus lanceolatus ? *Linn.* (Spear Thistle.) Rare, fruit small.
Lapsana communis, *Linn.* (Nipplewort.) Pakefield.
Picris hieracioides, *Linn.* Pakefield.
Menyanthes trifoliata, *Linn.* (Bog Bean.) Common.
Lycopus europæus, *Linn.* (Gipsywort.) Mundesley and Pakefield.
Stachys palustris, *Linn.* Beeston.
Atriplex patula, *Linn.* Common.
[Suæda maritima, *Dum.*] A doubtful determination. Perhaps Atriplex.
Polygonum, sp. Pakefield.
Rumex maritimus, *Linn.* (Golden Dock.) Common.
——— crispus ? *Linn.* (Curled Dock.) Sidestrand.
——— Acetosella, *Linn.* (Sheep Sorrel.) Beeston.
Euphorbia amygdaloides, *Linn.* (Wood Spurge.) Mundesley and Pakefield.
Ulmus, sp. (Elm.) Happisburgh only.
Betula alba, *Linn.* (Birch.) Common.
Alnus glutinosa, *Linn.* (Alder.) Common.
Carpinus Betulus, *Linn.* (Hornbean.) Abundant at Pakefield.
Corylus Avellana, *Linn.* (Hazel.) Ostend and Pakefield—rare.
Quercus Robur, *Linn.* (Oak.) Common.
Fagus sylvatica *Linn.* (Beech.) Happisburgh only.
Salix cinerea, *Linn.* [Mundesley—A. G. Nathorst.]
——— 2 sp. (Willows.) Badly preserved leaves of two other species occur.
Ceratophyllum demersum, *Linn.* (Hornwort.) Common.

Gymnosperms.

Taxus baccata, *Linn.* (Yew.) Common.
Pinus sylvestris, *Linn.* (Scotch Fir.) Abundant.
——— abies, *Linn.* (Spruce.) Abundant.

Monocotyledons.

Sparganium ramosum, *Curtis.* (Bur Reed.) Common at Pakefield.
Alisma Plantago, *Linn.* (Water Plantain.) Common.
Potamogeton heterophyllus, *Schreb.* (Pondweed.) Abundant.
——————— lucens, *Linn.* Pakefield and near Cromer.
——————— prælongus, *Wulf.* Lower Freshwater Bed near Cromer.
——————— crispus, *Linn.* Abundant.
——————— trichoides, *Cham.* Abundant.
——————— pectinatus, *Linn.* Abundant.
Zannichellia palustris, *Linn.* (Horned Pondweed.) Common.
Scirpus pauciflorus, *Lightf.* (Sedge.) Common.
——— cæspitosus, *Linn.* Abundant.
——— fluitans, *Linn.* Beeston.
[——— setaceus, *Linn.*] A wrong determination.
——— lacustris, *Linn.* Common.
Eriophorum angustifolium, *Roth.* (Cotton Grass.) Cromer and Corton.
[Cladium germanicum, *Schrad.*] A wrong determination.
Carex remota, *Linn.* (Sedge.) Pakefield.
——— paludosa, *Good.* Pakefield.
——— riparia, *Curtis.* Overstrand and Pakefield.
Phragmites communis, *Trin.* (Reed.) Common.

Cryptogams.

Osmunda regalis, *Linn.* (Royal Fern.) Common.
Isoëtes lacustris, *Linn.* Beeston, one macrospore.
Brachythecium plumosum, *Swartz.* Pakefield.
Amblystegium fluitans, *Mitt.* Pakefield.
Eurynchium Swartzii, *Turn.* Pakefield.

TABLES OF FOSSILS.

Section II.—Fauna of the Sea.

Table VI.—Vertebrata.

(By E. T. Newton, F.G.S., F.Z.S.)

	Nodule Bed.*	Coralline Crag.	Norwich Crag.	Weybourn Crag.	Forest-bed.	Pleistocene.	Living.	Extinct.	
Mammalia.									
(Carnivora.)									
Phoca barbata, *Fab.*	..	..	..	..	×	..	×		
—— Moori, *Newt.*	×	..	..	..	..	..	..	×	
Phocanella minor, *Van Ben.*	×	..	..	..	..	..	..	×	
Trichechus Huxleyi, *Lank.*	×	..	×	..	×	..	..	×	
(Sirenia.)									
Halitherium Canhami, *Flower*	×	..	..	..	..	..	..	×	
(Cetacea.)									
Balæna biscayensis, *Gray*	..	..	..	..	×	..	×		
—— affinis, *Owen*	×	..	..	..	..	..	..	×	
—— primigenia, *Van Ben.*	×	..	..	..	..	..	..	×	
—— insignis, *Van Ben.*	×	..	..	..	..	..	..	×	
—— balænopsis, *Van Ben.*	×	×	..	..	..	..	..	×	
—— sp.	..	..	..	..	..	..	..	?	Chillesford Clay.
Megaptera affinis, *Van Ben.*	×	×	..	..	..	..	..	×	
—— similis, *Van Ben.*	×	..	..	..	..	..	..	×	
—— minuta, *Van Ben.*	..	×	..	..	..	..	..	×	
Balænoptera definita, *Owen*	×	..	..	..	..	..	..	×	
—— Goropi, *Van Ben.*	×	..	..	..	..	..	..	×	
—— borealina, *Van Ben.*	×	..	..	..	..	..	..	×	
—— emarginata, *Owen*	×	..	..	..	..	..	..	×	
—— sp.	..	..	..	..	×	..	?		
Cetotherium Brialmonti, *Van Ben.*	×	..	..	..	..	..	..	×	
—— dubium, *Van Ben.*	×	..	..	..	..	..	..	×	
—— Hupschi? *Van Ben.*	×	..	..	..	..	..	..	×	
—— brevifrons, *Van Ben.*	×	..	..	..	..	..	..	×	
Herpetocetus scaldiensis, *Van Ben.*	×	..	..	..	..	..	..	×	
Physeter macrocephalus, *Linn.*	..	..	..	..	×	..	×		
Eucetus amblyodon, *Du Bus*	×	..	..	..	..	..	..	×	
Balænodon physaloides, *Owen*	×	..	..	..	..	..	..	×	

* A few of the specimens in the Nodule Bed may belong to the Red Crag, but at present they cannot be separated (see p. 15).

TABLE VI.—*continued.*

—	Nodule Bed.	Coralline Crag.	Norwich Crag.	Weybourn Crag.	Forest-bed.	Pleistocene.	Living.	Extinct.	—
Physeterula Dubusi? *Van Ben.*	×	..	..	..	..	..	..	×	
Physodon grandis? *Du Bus*	×	..	..	..	..	..	..	×	
——— fusiformis? *Du Bus*	×	..	..	..	..	..	..	×	
Hoplocetus borgerhoutensis? *Du Bus*	×	..	..	..	..	..	..	×	
——— crassidens? *Gerv.*	×	..	..	..	..	..	..	×	
——— curvidens? *Gerv.*	×	..	..	..	..	..	..	×	
Hyperoodon, sp.	×	..	..	..	..	..	..	?	
Choneziphius planirostris, *Cuv.*	×	×	..	..	..	..	..	×	
——— planus, *Owen.*	×	..	..	..	..	..	..	×	
——— Packardi, *Lank.*	×	..	..	..	..	..	..	×	
Mesoplodon longirostris, *Cuv.*	×	..	..	..	..	..	..	×	
——— tenuirostris, *Owen.*	×	..	..	..	..	..	..	×	
——— gibbus, *Owen*	×	..	..	..	..	..	..	×	
——— angustus, *Owen*	×	..	..	..	..	..	..	×	
——— angulatus, *Owen*	×	..	..	..	..	..	..	×	
——— compressus, *Huxley*	×	..	..	..	..	..	..	×	
——— Floweri, *Canham MS.*	×	..	..	..	..	..	..	×	Non M. Floweri, *v. Haast.*
——— scaphoides, *Newt.*	×	..	..	..	..	..	..	×	
Squalodon antwerpiensis, *Van Ben.*	×	..	..	..	..	..	..	×	
Orca citoniensis, *Capellini*	×	..	..	..	..	..	..	×	
Globicephalus uncidens, *Lank.*	×	×	..	..	..	..	..	×	
Monodon monoceros, *Linn.*	?	..	..	..	×	×	×		
Delphinapterus leucus, *Pallas*	..	..	..	..	×	×	×		
Delphinus delphis, *Linn.*	..	..	×	..	×	..	×	..	Aldeby.
Tursiops tursio? *Bonn.*	..	×	..	..	×	..	?		
Phocæna communis, *Linn.*	..	..	..	..	×	..	×		
PISCES.									
Chrysophrys	×	×	×	×	..	..	..	?	
Platax Woodwardi, *Ag.*	×	×	×	×	×	..	..	×	
Anarrhichas lupus, *Linn.*	..	×	..	..	..	..	×		
Gadus morhua, *Linn.*	..	?	×	..	×	..	×		
——— pseudo-æglefinus, *Newt.*	..	×	×	×	..	..	..	×	Allied to Haddock. Also in Red Crag?
——— luscus, *Linn.*	..	×	..	..	..	×	×	..	Red Crag.
——— minutus? *Linn.*	..	×	..	..	..	..	×		
——— merlangus, *Linn.*	..	?	..	..	..	..	×	..	Also St. Erth.
——— virens? *Linn.*	..	?	..	..	..	..	×		
——— pollachius, *Linn.*	..	?	×	×	..	..	×		
——— elegans, *Koken*	..	×	..	..	..	..	..	×	Red Crag?

TABLE VI.—*continued.*

	Nodule Bed.	Coralline Crag.	Norwich Crag.	Weybourn Crag.	Forest-bed.	Pleistocene.	Living.	Extinct.	
Labrus	×	..	..	..	..	..	×		
Thynnus thynnus, *Linn.*	..	..	..	..	×	..	×		
——— scaldiensis, *Storms.*	..	×	..	..	..	..	..	×	Also Scaldisian.
Pleuronectes	..	..	..	..	×	..	×		
Arius	×	..	..	..	..	..	..	×	Eocene.
Phyllodus	×	..	..	..	..	..	..	×	London Clay.
Pisodus	×	..	..	..	..	..	..	×	Derived.
Pycnodus	×	..	..	..	..	..	..	×	London Clay.
Gyrodus	×	..	..	..	..	..	..	×	Derived.
Lepidotus	×	..	..	..	..	..	..	×	Derived.
Acipenser	×	..	×	..	×	..	×		
Cælorhynchus	×	..	..	..	..	..	..	×	Eocene.
Edaphodon	×	..	..	..	..	..	..	×	Derived.
Elasmodus Hunteri, *Eg.*	×	..	..	..	..	..	..	×	Eocene.
Galeus canis, *Linn.*	..	..	..	×	..	..	×	..	Also St. Erth.
——— sp.	×	..	..	..	..	..	..	×	
Cetorhinus maximus, *Cuv.*	×	..	..	..	..	..	..	×	
Carcharodon megalodon, *Ag.*	×	..	..	..	..	..	..	×	Also Nod. Bed of of Cor. Crag?
——— Rondeleti, *Müll. & H.*	×	×	..	..	..	..	×		
Lamna (Otodus) obliquus, *Ag.*	×	..	..	..	..	..	..	×	Derived?
Oxyrhina hastalis, *Ag.*	×	×	..	..	..	..	..	×	Including O. xiphodon.
Odontaspis contortidens, *Ag.*	×	..	..	..	..	..	..	×	Part derived.
——— elegans, *Ag.*	×	..	..	..	..	..	..	×	Part derived.
Notidanus gigas, *Sismonda*	×	..	..	..	..	..	..	×	
Ptycodus polygyrus, *Ag.*	×	..	..	..	..	..	..	×	Chalk.
Aetobatis	×	..	..	..	..	..	..	×	Eocene.
Rhinoptera Woodwardi, *Ag.*	..	..	×	..	..	..	..	×	
Myliobatis Dixoni, *Ag.*	×	..	..	..	..	..	..	×	Eocene.
——— toliapicus, *Ag.*	×	..	..	..	..	..	..	×	Eocene.
Raia clavata, *Linn.*	×	×	×	×	..	..	×		
——— batis, *Mont.*	..	×	..	×	..	..	×		
——— sp.	..	×	..	..	..	..	..	?	
Pristis	×	..	..	..	..	..	..	×	Eocene.
Squatina	×	..	..	..	..	..	..	?	Derived?
Acanthias vulgaris, *Risso*	..	..	..	×	..	..	×		

Further information, and lists of rejected species, will be found in E. T. Newton's Memoir on. "The Vertebrata of the Forest-Bed Series," *Geol. Survey*; and in a forthcoming Memoir on the Pliocene vertebrata, also *Geol. Survey*.

Table VII.—Marine Mollusca of the North European Pliocene Strata.

The "Crag Mollusca" of Searles V. Wood is taken as the foundation of these lists, and the names adopted by Wood are used, except where there is a general consensus of opinion that they are incorrect, or should be replaced by names of earlier date. Where there is a difference of opinion other views are noticed in the column for remarks, and initialled thus: G. J. = Gwyn Jeffreys; G. D. = Gustave Dollfus; K. & B. = Kendall and Bell; E. v. B. = E. van den Broeck; C. R. = Clement Reid. Where the corrections of Jeffreys have been accepted by Wood the necessary alteration has been made in the list. A few additional species recorded by Jeffreys, but not referred to by Wood, are also included, though it is possible that Wood purposely omitted them. Cols. 15 and 16 show which species have a range exclusively north or south of Britain.

The authorities for the different horizons are:—

Col. 1. Box Stones, E. Ray Lankester.
,, 2. Coralline Crag, S. V. Wood.
,, 3. Lenham Beds, Clement Reid.
,, 4. Diestian of Belgium, Nyst and Van den Broeck.
,, 5. St. Erth Beds, Kendall and Bell.
,, 6. Normandy, Gustave Dollfus.
,, 7. Red Crag of Walton, S. V. Wood, and R. Bell.
Col. 8. Scaldisian of Antwerp, Nyst and Van den Broeck.
,, 9. Red Crag of Butley, &c., S. V. Wood.
,, 10. Norwich Crag, S. V. Wood.
,, 11. Chillesford Crag, S. V. Wood.
,, 12. Weybourn Crag, Clement Reid.
,, 13. Forest-bed, Clement Reid.

——	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	——
PTEROPODA.																		
Cleodora infundibulum, *S. Wood* - -	..	×	..	..	..	..	..	..	..	..	..	..	..	?	..	..	..	Clio caudata, *Linn.* (G. J.).
Spirialis rostralis, *Eyd. & Soul.* - -	..	..	..	?	..	..	..	?	..	..	..	..	..	..	..	..	×	Horizon doubtful.
.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

GASTEROPODA.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
Aclis, see Alvania and Odostomia.																		
Actæon? Etheridgii, *A. Bell*	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	Deep Atlantic (G. J.).
——— levidensis, *S. Wood*	..	×	..	?	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— Noæ, *J. Sow.*	..	..	..	..	..	..	×	×	×	×	..	..	..	..	..	..	×	A. pusillus, *Forbes* (G. J.).
——— subulatus, *S. Wood*	..	×	..	×	..	..	×	..	×	..	..	..	..	..	..	..	×	A. tornatilis, var. (G. J.).
——— tornatilis, *Linn.*	..	×	×	×	..	..	×	..	×	×	×	..	..	×				
Adeorbis naticoides, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	A very doubtful species (S. W.).
——— pulchralis, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Margarita trochoidea, *S. Wood* (G. J.).
——— striatus, *Phil.*	..	×	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×	Trochus Duminyi, *Req.* (G. J.).
——— subcarinatus, *Mont.*	..	×	..	×	..	×	×	×	×	..	..	..	..	×				
——— supranitidus, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— tricarinatus, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	A. supranitidus, var. (G. J.).
Admete, see Cancellaria.																		
Alvania albella, *Leach*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	Aclis Walleri, *Jeff.* (S. W.).
——— supranitida, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	In part A. ascaris (G. J.).
Amaura candida, *Möll.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×		
——— hesterna, *S. Wood*	..	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
Amauropsis, see Natica.																		
Anellum, see Cæcum.																		
Aporrhais pespelicani, *Linn.*	..	×	×	×	..	..	×	×	×	×	..	..	..	×				
Assiminea Grayana? *Leach*	..	..	..	..	..	..	..	..	..	×	..	..	..	×	..	..	..	A very doubtful determination.
Astyris, see Columbella.																		

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Bela, see Pleurotoma.																		
Bittium, see Cerithium.																		
Brochina, see Cæcum.																		
Buccinum Dalei, *J. Sow.*	..	×	×	×	..	×	×	×	×	×	×	..	..	×				
——— declive, *S. Wood*	..	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
——— glaciale, *Linn.*	..	..	..	..	..	..	×	..	?	..	..	..	..	..	..	×		
——— nudum, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— pseudo-Dalei, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— Tomlinei, *Canham*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative? (S. W.).
——— undatum, *Linn.*	..	×	..	×	..	..	×	×	×	×	×	×	..	×				
Bulla acuminata, *Brug.*	..	×	..	×	..	..	..	×	..	..	..	..	..	×				
——— alba, *Brown*	..	..	..	..	..	..	..	..	..	×	..	×	..	×				
——— concinna, *S. Wood*	..	×																
——— conuloidea, *S. Wood*	..	×	..	×	..	..	..	×	..	..	..	..	..	..	..	..	×	B. umbilicata, *Mont.*, var. (G. J.).
——— cylindracea, *Penn.*	..	×	..	×	..	×	..	×	×	..	..	..	..	×				
——— hyalinus, *Turt.*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
—— Lajonkaireana, *Bast.*	..	×	..	..	..	..	..	..	..	×	..	..	..	..	?	..	..	B. mamillata, *Phil.* ? (S. W.). Utriculus obtusus, var. (G. J.). Yarn Hill (R. E. Leach.).
—— nana, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	?			
—— regulbiensis, *Adams*	..	..	..	..	..	×	..	..	..	×	×	..	..	×	..	..	..	Utriculus obtusus, *Mont.* (S. W.). B. mamillata, *Phil.* (G. D.).
—— truncata, *Adams*	..	×	..	..	×	..	..	..	..	×	×	..	..	×				
—— utriculus ? *Brocc.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	B. miliaris ? not B. utriculus (S. W.).
Bullæa catena, *Mont.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— quadrata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— scabra, *Müll*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— ventrosa, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	?			
Cæcum glabrum, *Mont.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— liratum, *Carp.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— mammillatum, *S. Wood*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	Living, Japan (G. J.).
—— tumidum, *Carp.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	C. mammillatum, var. (G. J.).
Calyptræa chinensis, *Linn.*	..	×	..	×	×	×	×	×	×	×	×	..	..	×				
Cancellaria avara ? *Say*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative ? (S. W.). Living, North America ?
—— Bellardi, *Mich.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative ? (S. W.).
—— Bonellii, *Bellardi*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative in Red Crag ? (S. W.).
—— cancellata ? *Linn.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
—— ? Charlesworthii, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
—— contorta, *Bast.*	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— crassistriata, *A. Bell*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
—— gracilenta, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— mitræformis, *Broc.*	..	×	..	..	..	..	..	×	×	..	..	..	..	..	×			

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Cancellaria occulta, *Beyr.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
——— scalaroides, *S. Wood*	..	×	..	×	..	..	×	×	×	..	..	..	..	..	..	..	×	C. varicosa, *Broc.* (G. J.). C. Lajonkairi, *Nyst.*
——— spinulosa ? *Broc.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— subangulosa, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Admete Reedii, *A. Bell* (S. W.).
——— umbilicaris ? *Broc.*	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	..	×	Derivative in Red Crag (S. W.).
——— viridula, *Fab.*	..	..	..	..	..	..	..	×	×	×	..	×	..	..	..	×		
Capulus fallax, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Piliscus commodus, *Midd.* (G. J.).
——— obliquus, *S. Wood*	..	×	..	..	..	..	×	×	×	..	..	..	..	..	..	..	×	C. ungaricus, var. (G. J., Nyst).
——— partim-sinuosus, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	?	A doubtful species (S. W.).
——— recurvatus, *S. Wood*	..	×	..	..	..	..	×	..	×	..	..	..	..	×	..	..	..	C. militaris, *Mont.* non *Linn.* (S. W.). C. ungaricus, jun. (G. J., Nyst).
——— sinuosus, *Broc.*	..	×	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	Doubtful species (S. W.). C. ungaricus, var. (Nyst).
——— ungaricus, *Linn.*	..	×	..	×	..	×	×	×	×	?	..	..	..	×				
Cassidaria bicatenata, *J. Sow.*	×	×	..	×	..	..	..	×	×	..	..	..	..	..	?	..	..	Derivative in Red Crag ? (S. W.). C. tyrrhena, var. ? (G. J.).
Cassis Saburon, *Brug.*	..	..	..	×	..	..	..	×	×	..	..	..	..	..	×	..	..	Derivative in Red Crag (S. W.).
Cemoria noachina, *Linn.*	..	?	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	Specimen lost (S. W.).
Cerithiopsis lactea ? *Möll.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×		
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
——— tuberculatus, *Mont.*	..	×	..	×	..	×	..	..	×	×	..	..	..	×				
Cerithium aberrans, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Specimen lost (S. W.).
——— cribrarium, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Living, deep Atlantic (G. J.).
——— derivatum, *S. Wood*	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×	Derivative (S. W.).
——— granosum, *S. Wood*	..	×	..	×	..	..	×	..	?	..	..	..	..	..	..	..	×	C. Macandrei, *H. Adams* (G. J.).
——— Greenii ? *Adams*	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	Living, North America ?
——— Metaxa, *Delle Ch.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— perpulchrum, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	?	..	..	C. mamillatum ? *Risso* (S. W.).
——— perversum, *Linn.*	..	×	..	..	..	×	×	×	..	..	..	..	..	×				
——— reticulatum, *Da C.*	..	..	..	..	×	×	?	..	?	?	..	..	..	×	..	..	..	C. scaber, *Olivi* (G. D.).
——— tricinctum, *Broc.*	..	×	×	..	..	×	×	×	×	×	×	..	..	..	..	..	×	
——— trilineatum, *Phil.*	..	×	..	..	..	..	×	..	..	..	..	..	..	..	×			
——— variculosum, *Nyst.*	..	..	..	..	..	..	×	×	×	..	..	..	..	..	..	..	×	C. reticulatum, var. (G. J.).
Chemnitzia clathrata, *Jeff.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
— ——— costaria, *S. Wood*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	×	..	..	Derivative in Red Crag (S. W.).
——— costellata, *Gratel.*	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	×	
——— densecostata ? *Phil.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	Odostomia rufa, var. (G. J.).
——— elegantior, *S. Wood*	..	×	..	×	..	..	×	..	×	..	..	..	..	..	..	..	×	O. lactea (G. J.).
——— filosa, *S. Wood*	..	×	..	..	..	..	..	?	..	..	..	..	..	..	?	..	..	Parthenia varicosa, *Forbes* ? (S. W.).
——— fenestrata, *F. & H.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×				
——— indistincta ? *Mont.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— internodula, *S. Wood*	..	×	..	..	..	..	×	×	×	×	..	..	..	..	×	..	..	C. corbis, *Conti* (G. J.).
——— Jeffresii ? *Weichman*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	A doubtful determination (S. W.).

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Chemnitzia nitidissima ? *Mont.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	Not nitidissima, but allied to O. acicula (G. J.).
——— perexilis, *S. Wood*	..	×	..	..	..	?	..	..	..	..	..	..	..	..	..	..	×	C. lactea, *Linn.* (G. D.).
——— plicatula ? *Broc.*	..	..	..	..	×	..	×	..	×	..	×	..	..	..	..	..	×	
——— rufa, *Phil.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	A doubtful identification (G. J.).
——— rugulosa, *S. Wood*	..	..	..	..	..	..	×	..	..	×	..	..	..	..	..	..	×	A provisional species (S. W.).
——— Scillæ, *Scac.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×				
——— senistriata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— similis, *S. Wood*	..	×	..	×	..	×	..	×	..	..	..	..	..	..	..	..	×	O. filosa, var. (G. J.). Eulimella affinis, *Phil.* (G. D.).
——— varicula, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Living, deep Atlantic (G. J.). Gen. Cerithium (G. J.).
Clavatula, see Pleurotoma.																		
Columbella abbreviata, *A. Bell*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
——— Borsoni ? *Bell*	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×	A doubtful identification (S. W.). C. subulata, *Broc.* ? (G. D.).
——— erythrostoma ? *Bonani*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
——— minor, *Scac.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
——— subulata, *Broc.*	..	..	..	..	..	×	..	×	..	..	..	..	..	..	?	..	..	C. scripta, *Linn.* Perhaps C. Borsoni (E. v. B.).
——— sulcata, *J. Sow.*	..	×	..	..	×	..	×	×	×	?	..	..	..	..	..	..	×	
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
——— sulculata, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
Conopleura, see Pleurotoma.																		
Conovulus, see Melampus.																		
Conus Dujardinii, *Desh.*	×	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×	
Cyclostrema lævis, *Phil.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	C. basi-striatum ? (S W.).
——— nitens, *Phil.*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
——— ? sphæroidea, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
Cylichna, see Bulla.																		
Cypræa affinis, *Duj.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	C. avellana, var. (G. J.).
——— Angliæ, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	C. retusa, var. ? (S. W.). C. retusa, var. (G. J.).
——— avellana, *J. Sow.*	..	×	..	?	×	?	×	..	×	..	..	..	..	..	..	..	×	
——— europæa, *Mont.*	..	×	×	×	..	×	×	×	×	..	..	..	..	×				
——— retusa, *J. Sow.*	..	×	..	..	..	..	..	×	×	..	..	..	..	..	..	..	×	
Defrancia, see Pleurotoma.																		
Elephantulum, see Cæcum.																		
Emarginula crassa, *J. Sow.*	..	×	..	..	..	..	×	×	×	..	..	..	..	×	..	..	..	Only var. crassalta in Coralline Crag (S. W.).
——— fissura, *Linn.*	..	×	×	..	..	×	×	×	×	..	..	..	..	×				
Erato lævis, *Don.*	..	×	..	..	..	×	×	..	×	..	..	..	..	×	..	..	..	Derivative in Red Crag ? (S. W.).
——— Maugeriæ, *Gray*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	×	..	..	Living, West Indies. Derivative in Red Crag ? (S. W.).
Eulima bilineata ? *Alder*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	A doubtful identification (S. W.).
——— glabella, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	E. Stalioi, *Brus.* (G. J.).
——— Hebe, *Semper*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— intermedia, *Cantr.*	..	×	..	×	×	..	×	..	×	..	..	..	..	×				

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Eulima Naumanni? *von Koenen*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— polita, *Linn.*	..	×	..	..	×	..	×	..	..	..	..	..	..	×				
—— robusta, *A. Bell*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
—— similis? *D'Orb.*	..	..	..	..	..	..	×	..	..	..	..	..	..	..	?	..	..	E. distorta, *Phil.* (G. J.).
—— subula, *D'Orb.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— subulata, *Bon.*	..	×	?	×	..	..	×	×	..	..	..	..	..	×	..	..	..	Not E. subulata (G. J.).
Eulimella acicula, *Phil.*	..	×	..	..	..	..	×	..	..	×	..	..	..	×				
Eulimene pendula, *S. Wood*	..	..	..	..	..	..	×	..	×	..	..	..	..	..	..	..	×	E. terebellata, var. (G. J.).
—— terebellata, *Nyst*	..	..	..	..	×	..	×	×	×	..	..	..	..	..	..	..	×	
Fartulum, see Cæcum.																		
Ficula, see Pyrula.																		
Fissurella costaria, *Bast.*	..	×	..	..	×	..	..	×	..	..	..	..	..	..	×	..	..	Derivative in Red Crag? (S. W.).
—— græca, *Linn.*	..	×	×	..	..	..	×	×	×	..	..	..	..	×				
Fossarus lineolatus, *S. Wood*	..	×	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×	F. japonicus, *A. Adams* (G. J.).
—— sulcatus, *S. Wood*	..	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	F. costatus, *Broc.* (G. J.).
Fusus abrasus, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
—— corneus, *Linn.*	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×			
—— crispus, *Bors.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
—— ? exacutus, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— imperspicuus, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— lamellosus, *Bors.*	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Cor. Crag (C. R.).
—— nodifer, *A. Bell*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
—— ? obscurus *S. Wood*	..	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
—— Waelli, *Nyst*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
——, see also Trophon.																		
Homalogyra atomus, *Phil.*	..	×	..	..	×	..	..	..	..	..	..	..	..	×				
—— rota, *F. & H.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×				
Hydrobia obtusa, *Sandb.*	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×	
—— subumbilicata, *Mont.*	..	..	..	..	..	..	..	..	..	×	×	×	..	×	..	..	..	H. ventrosa, *Mont.* (G. J.).
—— ulvæ, *Pen.*	..	..	..	..	..	..	?	..	..	×	×	..	..	×				
Jeffreysia diaphana, *Alder*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
—— globularis, *Jeff.*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
Lachesis anglica, *A. Bell*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Lacuna Basteroti, *Bronn*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
—— crassior, *Mont.*	..	..	..	..	..	..	..	..	..	?	..	..	..	×				
—— reticulata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Gen. Fossarus (G. J.).
—— suboperta, *J. Sow.*	..	..	..	..	×	..	×	×	×	..	..	..	..	..	..	..	×	Littorina littorea, var. (G. J.).
—— vincta, *Mont.*	..	..	..	..	..	..	..	..	..	×	..	..	..	×	..	..	..	L. divaricata.
Lepeta, see Tectura.																		

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern	Extinct.	—
Litiopa ? papiliosa, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Littorina littorea, *Linn.*	..	..	..	..	..	..	..	..	×	×	×	×	×	×				
——— rudis, *Maton*	..	..	..	..	..	..	..	..	..	×	×	×	×	×				
Margarita argentata, *Gould*	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	×		
——— crassi-striata, *R. Bell*	..	..	..	..	..	..	..	..	?	..	..	..	..	..	..	..	×	
——— groenlandica, *Chemn.*	..	..	..	..	..	..	..	..	..	×	..	..	..	×				
——— maculata, *S. Wood*	..	×	..	×	..	..	×	?	..	..	..	..	..	..	..	..	×	Trochus turbinoides, *Nyst.*
——— trochoidea, *S. Wood*	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Marginella clandestina, *Broc.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
Marsenia tentaculata, *Linn.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	Lamellaria perspicua, *Linn.* (G. J.).
Melampus fusiformis, *S. Wood*	..	..	..	..	..	..	..	..	×	×	×	..	..	..	..	..	×	Aldeby (C. R.).
——— pyramidalis, *J. Sow.*	..	..	..	..	×	..	×	×	×	×	×	×	×	..	..	..	×	Italian Pliocene (C. R.).
Menestho albula, *Fabr.*	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×		
——— britannica, *A. Bell*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— lævigata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— Jeffreysii, *A. Bell*	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	Rissoa costulata, worn (S. W.).
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
—— suttonensis, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Mitra aperta, *Bellardi*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
—— ebenus, *Lam.*	..	×	..	..	..	×	..	..	×	..	..	..	..	..	×	..	..	Derivative in Red Crag? (S. W.). M. cornicula, *Linn.* (G. J.).
—— fusiformis, *Broc.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	×	..	..	Derivative? (S. W.).
Murex Canhami, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Unique and possibly derivative (S. W.).
—— corallinus, *Scac.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	M. aciculatus, *Lam.* (G. J.).
—— Crowfootii, *S Wood.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
—— Duponti, *Nyst*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
—— erinaceus, *Linn.*	..	..	..	..	..	..	..	..	×	×	..	..	..	×				
—— insculptus, *Dujard.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
—— pseudo-Nystii, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
—— recticanalis, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	A provisional species (S. W.).
—— Reedii, *S. Wood*	..	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
—— tortuosus, *J. Sow.*	..	×	..	..	..	..	×	×	×	..	..	..	..	..	..	..	×	Derivative in Red Crag? (S.W.). M. erinaceus, var. (G. J.).
Nassa angulata, *Broc.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
—— conglobata, *Broc.*	×	..	..	..	..	..	×	..	×	..	..	..	..	..	..	..	..	Living, Senegal? (S. W.). Derivative in Red Crag (S.W.).
—— consociata, *S. Wood*	..	×	..	..	..	..	..	×	×	..	..	..	..	..	..	..	×	Derivative in Red Crag? (S. W.). N. elegans, var. (G. J.).
—— costulata, *Ren.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
—— Cuvieri, *Payr.*	..	..	..	..	..	..	..	..	×	×	..	..	..	..	×			
—— densecostata, *A. Bell*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— elegans, *Leathes*	..	..	..	..	..	..	×	×	..	..	..	..	..	..	..	..	×	Living, Atlantic (G. J.).
—— gibbosula, *Broc.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
—— granifera, *Duj.*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative in Red Crag? (S. W.).

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Nassa granulata, *J. Sow.*	..	×	..	..	×	..	×	×	×	..	..	..	..	..	..	..	..	Living, Japan? (S. W.).
—— incrassata, *Müll.*	..	×	..	..	..	..	..	×	×	..	×	..	..	×	..	..	..	
—— labiosa, *J. Sow.*	..	×	..	..	..	..	×	×	×	..	..	..	..	..	..	..	×	Derivative in Red Crag? (S. W.). N. semistriata, *Broc.* (G. J.)
—— lamellilabra, *Nyst*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
—— limata, *Chem.*	..	×	..	..	..	×	×	..	×	..	..	..	..	..	×	..	..	N. microstoma, *S. Wood.* Boyton, horizon doubtful (S. W.).
—— monensis, *Forbes*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	An uncertain species (S. W.). N. reticosa, var.? (S. W.). N. incrassata, var. (G. J.).
—— musiva, *Broc.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
—— mutabilis, *Linn.*	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×			
—— prismatica, *Broc.*	..	×	×	..	..	×	..	×	..	..	..	..	..	..	×			
—— propinqua, *J. Sow.*	..	..	..	..	..	..	×	×	×	..	..	..	..	..	..	..	×	N. trivittata, *Say* (G. J.).
—— pulchella, *Andr.*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative in Red Crag? (S. W.).
—— pygmæa, *Lam.*	..	?	..	..	..	..	..	?	?	..	..	..	..	×	..	..	..	N. incrassata, var. (G. J.).
—— reticostata, *Bellardi*	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	×	
—— reticosa, *J. Sow.*	..	..	..	×	×	..	×	×	×	..	×	..	..	..	..	..	×	N. serrata, *Broc.* (G.J.).
Natica Alderi, *Forbes*	..	×	..	×	..	..	..	..	..	×	..	..	..	×				
—— catena, *Da C.*	..	..	..	..	..	..	×	×	×	×	×	×	?	×				
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
—— catenoides, *S. Wood*	..	..	..	..	..	..	×	×	×	..	?	..	..	..	..	..	×	N. heros, *Say* ? (G. J.).
—— cirriformis, *J. Sow.*	..	×	..	×	..	×	..	×	×	..	..	..	..	..	..	..	×	N. sordida, *Swains.* (G. J.). N. intricata, *Donov.* (G. D.).
—— clausa, *Brod. & Sow.*	..	..	..	..	..	..	×	..	×	×	×	×	..	×	..	..	..	N. affinis, *Gm.* (G. J.).
—— grœnlandica, *Beck*	..	..	..	..	..	..	..	..	×	×	×	..	..	×				
—— Guillimini, *Phil.*	..	..	..	..	..	..	..	..	×	?	..	..	..	?	..	..	..	N. Alderi ? or N. catenoides, jun. (S. W.). N. catena, jun. (G. J.).
—— helicina ? *Broc.*	..	×	..	×	..	..	×	..	×	..	..	..	..	..	..	..	×	
—— hemiclausa, *J. Sow.*	..	..	..	×	..	×	×	×	×	?	×	×	..	..	..	..	×	N. macilenta, *Phil.* (G. D.).
—— islandica, *Gmel.*	..	..	..	..	..	..	..	..	×	×	×	×	..	×	..	..	..	N. helicoides, *Johnst.*
—— japonica ? *A. Adams*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	A doubtful identification (S. W.).
—— millepunctata, *Lam.*	..	×	×	×	×	×	×	×	×	..	?	..	..	..	×	..	..	N. multipunctata, *S. Wood* (G. J., Nyst, K. & B.).
—— occlusa, *S. Wood*	..	..	..	..	..	..	..	..	×	..	×	..	..	..	..	×		
—— proxima, *S. Wood*	..	×	..	?	×	..	..	..	?	×	..	..	..	..	?	..	..	N. sordida, *Phil.* ? (S. W.). N. cirriformis, var. (G. J.).
—— pusilla ? *Say*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A doubtful determination (S. W.).
—— triseriata ? *Say*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	A doubtful determination (S. W.).
—— varians, *Duj.*	..	×	×	×	..	..	×	?	×	..	..	..	..	..	..	..	×	N. cirriformis, var. (G. J.).
Neptunea, see Trophon.																		
Nodostoma ornata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— eulimelloides, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Odostomia albella, *Lovén*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— acicula, *Phil.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×				
—— acuta, *Jeff.*	..	×	..	..	×	..	×	..	..	..	..	..	..	×				
—— chrysalis, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	O. interstincta, var. (G. J.).
—— clathrata, *Jeff.*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Odostomia conoidea, *Broc.*	..	×	..	×	..	×	?	×	..	?	..	..	..	×				
——— conspicua, *Alder*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— dentiplicata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Odontostoma plicatum, *Speyer*? (S. W.).
——— derivata, *S. Wood*	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×	Doubtful species, probably derivative (S. W.).
——— eximia, *Jeff.*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
——— ? Gulsonæ, *Clark*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— insculpta, *Mont.*	..	×	..	..	×	..	..	..	..	..	..	..	..	×				
——— interstincta, *Mont.*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
——— obliqua, *Alder*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— ornata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— pallida, *Mont.* ¦	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
——— pellucida, *Adams*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	O. decussata, *Mont.* var. (G. J.).
——— plicata, *Mont.*	..	×	..	..	×	..	×	..	..	..	..	..	..	×	..	..	..	O. truncatula, *Jeff.* (G. J.).
——— Reevei, *S. Wood*	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×	Derivative? (S. W.).
——— rissoides, *Hanley*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
——— spiralis, *Mont.*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
——— unidentata, *Mont.*	..	..	..	..	×	..	×	..	..	..	..	..	..	×				
——— see also Chemnitzia.																		
Ovula spelta, *Linn.*	..	×	..	?	..	..	×	?	×	..	..	..	..	..	×			
Pileopsis, see Capulus.																		
Patella lusitanica, *Gmel.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
——— vulgata, *Linn.*	..	..	..	..	..	×	..	×	?	..	..	..	..	×				
Philine, see Bullea.																		
Pleurotoma assimilis, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
——— attenuata, *Mont.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— Bertrandi ? *Phil.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	×			
——— bicarinata, *Couth.*	..	..	..	..	..	..	..	..	×	?	..	..	..	..	..	..	..	Living, North America.
——— bipunctula, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	P. galerita, *Phil.* (G. J.).
——— brachystoma, *Phil.*	..	×	..	..	×	..	..	×	..	..	..	..	..	×	..	..	..	P. concinnata, var. (G. J.).
——— cancellata, *J. Sow.*	..	×	..	..	..	..	×	..	..	..	..	..	..	×	..	..	..	P. reticulata, var. ? (S. W.).
——— castanea, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— catenata, *A. Bell*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	An imperfect specimen. P. pannus, var. ? (S. W.).
——— clathratula ? *M. de S.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— consobrina, *Bellardi*	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Derivative ? (S. W.).
——— coronata, *Bellardi*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
——— costata, *Da C.*	..	×	..	..	×	×	×	×	×	..	..	..	..	×				
——— crassa, *A. Bell*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Raphitoma sigmoidea, *Bronn* ? (S. W.). P. incrassata (Nyst).
——— crispata, *Jan.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
——— curtistoma, *A. Bell*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	P. attenuata, var. (G. J.).

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	
Pleurotoma Dowsoni, *S. Wood*	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	×	
——— elegantula, *A. Bell*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	P. volvula, and P. notata, *A. Bell* (S. W.). P. attenuata (G. J.).
——— emarginata, *Don.*	..	..	..	..	..	..	..	×	..	..	..	..	..	×				
——— equalis, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
——— gracilior, *A. Bell*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	?	P. attenuata (S. W.).
——— gracilicostata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— granulina, *Nyst*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
——— harpula, *Broc.*	..	?	..	..	..	..	..	..	?	..	..	..	..	..	..	..	×	Boyton, horizon doubtful.
——— hispidula, *Jan.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
——— hystrix, *Jan.*	..	×	..	..	..	..	×	×	..	..	..	..	..	..	×			
——— Icenorum, *S. Wood*	..	×	..	..	..	..	..	?	×	..	..	..	..	..	..	..	×	Derivative in Red Crag ? (S. W.). P. semicolon, *Wood* non *Sow.* P. Woodii, *Nyst.* P. galerita, *Phil.* ? (G. J.).
——— incrassata, *Duj.*	..	?	..	..	..	..	..	×	..	..	..	..	..	..	×	..	..	Conopleura Maravignæ, *Biv.* (G. J.).
——— inermis, *Partsch*	..	×	..	×	..	..	..	..	..	..	..	..	..	?	..	..	..	P. nivalis, *Lovén* (G. J.).
——— interrupta, *Broc.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.),
——— intorta, *Broc.*	..	..	..	×	..	..	..	×	×	..	..	..	..	..	?	..	..	Derivative in Red Crag (S. W.).
——— Jouanneti, *Desm.*	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
——— lævigata, *Phil.*	..	?	..	..	..	..	×	..	×	..	..	..	..	×				
——— Leufroyii, *Mich.*	..	..	..	..	..	..	×	×	×	..	..	..	..	×				
——— linearis, *Mont.*	..	×	..	..	×	×	×	..	×	..	×	×	..	×				
——— mitrula, *J. Sow.*	..	×	..	..	..	×	×	..	×	..	..	..	..	..	?			
——— modiola, *Jan.*	..	×	..	×	..	..	×	×	..	..	..	..	..	?				
——— Morreni, *De Kon.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
——— nebula, *Mont.*	..	×	..	..	..	..	×	..	×	..	..	..	..	×				
——— nebulosa, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
——— nodifera ? *Lam.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
——— oblonga ? *Ren.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
——— pannus, *Bast.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— perpulchra, *S. Wood*	..	×	..	..	..	..	×	×	..	..	..	..	..	..	..	..	×	
——— Philberti, *Mich.*	..	×	..	..	..	..	×	..	..	..	..	..	..	..	×			
——— plicifera, *S. Wood*	..	..	..	×	..	..	..	..	×	..	..	..	..	..	?	..	..	P. elegans, *Möll.* (G. J.).
——— pyramidalis, *Ström.*	..	..	..	..	..	..	..	..	×	×	..	..	..	..	..	×		
——— quadricincta, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
——— rufa, *Mont.*	..	..	..	..	..	..	?	..	?	?	..	..	..	×				
——— scalaris, *Möll.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×		
——— senilis, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S.W.).
——— septangularis, *Mont.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×				
——— similis, *Nyst*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
——— striolata, *Phil.*	..	×	..	..	..	..	..	..	?	..	..	..	..	×				
——— subulata, *Nyst*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Pleurotoma Tarentini, *Phil.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	P. Renieri, *Phil.* (G. J.).
——— tenuistriata, *A. Bell*	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×	
——— teres? *Forbes*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— teredoides, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— trevelyana, *Turt.*	..	..	..	..	..	..	..	..	×	×	×	..	..	×				
——— turricula, *Mont.*	..	..	..	..	..	..	×	..	×	×	×	×	..	×				
——— turrifera, *Nyst*	..	..	×	×	..	..	×	×	×	..	..	..	..	..	..	..	×	P. turricula, *Broc.* non *Mont.*
Puncturella, see Cemoria.																		
Purpura lapillus, *Linn.*	..	..	..	..	..	..	×	×	×	×	×	×	×	×	..	..	..	Including var. incrassata, *Sow.*
——— tetragona, *J. Sow.*	..	..	..	..	..	..	×	×	×	?	..	..	..	..	..	..	×	P. lapillus, var. (G. J.).
Pyramidella plicosa, *Bronn*	..	×	..	×	..	..	×	..	..	..	..	..	..	..	×	..	..	P. læviuscula, *S. Wood.*
Pyrula reticulata, *Lam.*	×	×	×	×	..	×	×	..	×	..	..	..	..	..	×	..	..	Derivative in Red Crag? (S. W.). P. subintermedia, *Bronn.* (G. J.). P. acclinis, *S. Wood.*
Ranella? anglica, *A. Bell*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
Raphitoma submarginata, *Bellardi*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
Ringicula acuta, *Phil.*	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×			
——— buccinea, *Broc.*	..	×	..	×	..	×	..	..	×	..	..	..	..	..	×	..	..	R. auriculata, *Men.* (G. J.).
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
Ringicula ventricosa, *J. Sow.*	..	×	×	×	..	..	..	..	×	×	×	..	..	..	×	..	..	Gigantic var. at Lenham, perhaps new species (C. R.).
Rissoa abyssicola, *Forbes*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— concinna, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— confinis, *S. Wood*	..	×	..	..	..	×	..	..	..	?	..	..	..	..	..	..	×	A pulchella, *Phil.* (G. D.).
——— costulata, *Alder*	..	×	..	..	..	×	..	..	..	..	..	..	..	×				
——— crassi-striata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— crenulata, *Mich.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×	..	..	..	R. cancellata, *Da C.*
——— curticostata, *S. Wood*	..	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×	R. pulchella, *Phil.* (G. D.). Not R. pulchella (G. J.).
——— eximia ? *Jeff.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— glabrata, *Mühl.*	..	..	..	..	..	×	..	..	..	..	..	..	..	?				
——— granulum, *Phil.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
——— Montagui, *Payr.*	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×			
——— obsoleta, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	R. soluta, *Phil.* ? (G. D.).
——— parva, *Da C.*	..	×	..	..	..	×	..	..	..	..	..	..	..	×	..	..	..	R. simplex, *Phil.*
——— proxima, *Alder*	..	×	..	×	..	..	..	×	..	×	..	..	..	×				
——— pulchella, *Phil.*	..	?	..	..	..	×	..	..	?	?	..	..	..	..	×			
——— reticulata ? *Mont.*	..	×	..	..	×	..	..	..	..	..	..	..	..	×				
——— senecta, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Doubtful species (S. W.).
——— soluta, *Phil.*	..	×	..	..	..	×	..	..	..	..	..	..	..	..	×			
——— Stefanisi, *Jeff.*	..	×	..	×	..	..	×	..	..	..	..	..	..	..	×			
——— striata, *Mont.*	..	×	..	..	..	×	..	..	..	..	..	..	..	×				
——— vitrea, *Mont.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— Zetlandica, *Mont.*	..	×	..	..	..	×	×	..	×	..	..	..	..	×				

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

——	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-Bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	——
Scalaria ?cancellata, *Broc.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Not S. cancellata, *Broc.* (G. J.).
——— clathratula, *Adams*	..	×	×	×	..	×	..	×	..	?	..	..	..	×				
——— fimbriosa, *S. Wood*	..	×	..	..	..	×	..	×	..	..	..	..	..	..	..	..	×	S. lamellosa, *Broc.* var. (G. J.).
——— foliacea, *J. Sow.*	..	×	..	..	..	..	..	×	×	?	..	..	..	..	..	..	×	S. frondosa, var. (G. J.).
——— frondicula, *S. Wood*	..	×	..	×	..	..	..	×	..	..	..	..	..	..	..	..	×	
——— frondosa, *J. Sow.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	?	..	..	S. soluta, *Tiberi* ? (S. W.).
——— funiculus, *S. Wood*	..	×	..	..	..	..	×	..	×	..	..	..	..	..	..	..	×	
——— geniculata ? *Broc.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— grœnlandica, *Chemn.*	..	..	..	..	..	..	..	..	×	×	×	×	×	×				
——— hamulifera, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	S. fimbriosa, var. (G. J.).
——— Hennei, *Nyst*	..	..	..	×	..	..	..	..	..	..	..	..	..	..	?	..	..	S. deliculata, *H. Adams*? (Nyst).
——— ? obtusicostata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— subulata, *J. Sow.*	..	×	..	×	..	..	×	×	..	..	..	..	..	..	?	..	..	S. foliacea, var. (G. J.).
——— torulosa, *Broc.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Boyton, horizon doubtful (S. W.).
——— trevelyana, *Leach*	..	..	..	..	..	..	..	..	×	×	×	×	..	×				
——— Turtonis, *Turton*	..	..	..	..	..	..	..	..	..	..	×	×	..	×				
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
Scaphander librarius? *Lov.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— lignarius, *Linn.*	..	×	×	×	..	×	..	×	×	..	..	..	..	×				
Scissurella crispata, *Flem.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
Sigaretus excavatus, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Living, deep Atlantic (G. J.).
Sipho, see Trophon.																		
Skenea planorbis, *Fabr.*	..	..	..	..	×	..	..	..	..	..	..	..	..	×				
Solarium vagum, *S. Wood*	..	..	..	..	..	..	..	.	×	..	..	..	..	..	..	..	×	Derivative (S.W.).
Strombella, see Trophon.																		
Tectura fulva, *Müll.*	..	×	..	..	..	..	?	..	..	..	..	..	..	×				
——— parvula, *S. Woodw.*	..	..	..	..	..	..	..	..	..	×	..	..	..	?	..	..	..	Perhaps Patella vulgata, jun. (S.W.).
——— pellucida, *Linn.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×				
——— virginea, *Müll.*	..	×	..	..	..	..	×	×	×	..	..	×	..	×				
Terebra acuminata, *Bors.*	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— Basteroti, *Nyst.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
——— canalis, *S. Wood*	..	×	..	..	..	×	..	×	×	..	..	..	..	..	..	..	×	T. exilis, *Bell* (S.W.). T. inversa, var. (G. J.).
——— inversa, *Nyst*	..	×	..	×	..	..	..	×	×	..	..	..	..	..	..	..	×	Columbella minor, *Scac* ? (G. J.).
Trichotropis borealis, *Brod. & Sow.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
Triforis, see Cerithium.																		
Triton connectens, *S. Wood*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative in Red Crag (S. W.). T. cutaceus (G. J.). T. heptagonum, var. ?
——— heptagonum ? *Broc.*	..	..	×	..	..	..	..	..	..	..	..	..	..	..	?	..	..	Elongated variety (C. R.).
Trochus Adansoni, *Payr.*	..	×	..	?	×	..	×	×	×	..	..	..	..	..	×	..	..	Derivative in Red Crag (S. W.).
——— adriaticus, *Phil.*	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×	..	..	T. Adansoni, var. (K. & B.).
——— bullatus, *Phil.*	..	×	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×	

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

——	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-Bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	——
Trochus cinerarius, *Linn.*	..	..	×	..	..	..	×	..	×	..	..	..	..	×				
——— cineroides, *S. Wood*	..	..	..	..	..	..	×	×	×	..	..	..	..	..	..	..	×	T. cinerarius, var.; T. solarium, *Nyst* (G. J.).
——— conulus, *Linn.*	..	×	..	?	..	..	..	×	..	..	..	..	..	..	×	..	..	T. ziziphinus (G. J.).
——— ditropis, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	T. biangulatus, *Eich.* (G. J.).
——— formosus, *Forbes*	..	×	..	×	..	..	×	×	×	..	..	..	..	×	..	..	..	T. alibastrum, *Beck* (S. W.). T. occidentalis, *Migh.* (S. W., G. J.).
——— granulatus, *Born*	..	..	..	..	..	×	×	..	..	..	..	..	..	×				
——— Kicksii ? *Nyst*	..	×	..	..	..	..	×	?	×	..	..	..	..	..	×	..	..	T. Adansoni, var. (S. W., G. J.).
——— leucophæus ? *Phil.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×		
——— millegranus, *Phil.*	..	×	×	..	..	..	×	..	..	..	..	..	..	×				
——— Montacuti, *W. Wood*	..	×	..	..	..	..	×	×	×	..	..	..	..	×	..	..	..	Derivative in Red Crag ? (S. W.).
——— multigranus, *S. Wood*	..	×	..	×	..	..	×	×	×	..	..	..	..	×				
——— noduliferens, *S. Wood*	..	..	..	..	×	..	×	×	×	×	..	..	..	..	..	..	×	T. granulatus, var. ? (K. & B.).
——— obconicus, *S. Wood*	..	×	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
——— octosulcatus, *Nyst*	..	×	..	..	..	..	..	×	×	..	..	..	..	..	..	..	×	T. Adansoni, var. ? (S. W.).
——— sub-excavatus, *S. Wood*	..	..	..	..	..	..	×	?	×	..	..	..	..	..	..	..	×	T. noduliferens, var. ? (S. W.).
——— tricariniferus, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
—— turnidus, *Mont.*	..	..	..	..	..	..	×	..	×	×	×	?	..	×				
—— turbinoides, *Nyst*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	See Margarita maculata, *S. Wood.*
—— turgidulus ? *Broc.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— villacus, *Phil.*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	×	..	..	T. Adansoni, var. ? (G. J.).
—— zizyphinus, *Linn.*	×	×	×	×	×	..	×	×	×	?	..	..	..	×				
Trophon Actoni, *S. Wood*	..	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×	
—— alveolatus, *J. Sow.*	..	×	..	×	..	..	..	×	×	..	..	..	..	..	..	..	×	Derivative in Red Crag ? (S. W.).
—— altus, *S. Wood*	..	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×	
—— antiquus, *Linn.*	..	..	..	..	..	..	..	×	×	×	×	×	?	×				
—— —— var. contraria	..	..	..	..	..	..	×	×	×	×	×	×	?	×				
—— barvicensis, *Johnst.*	..	..	..	..	..	..	×	..	×	..	..	..	..	×				
—— berniciensis ? *King*	..	..	..	..	..	..	..	..	..	×	..	..	..	×				
—— consocialis, *S. Wood*	..	×	..	..	..	..	×	..	×	..	..	..	..	..	..	..	×	Derivative in Red Crag ? (S. W.). T. aveolatus, var. (G. J.).
—— costifer, *Nyst*	..	×	..	..	..	..	×	..	×	..	..	..	..	..	..	..	×	
—— craticulatus ? *Fabr.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×		
—— elegans, *Charlesw.*	..	×	..	..	..	..	..	×	×	..	..	..	..	..	..	..	×	Derivative in Red Crag ? (S. W.). Fusus antiquus, var. (G. J.).
—— gracilis, *Da C.*	..	×	..	..	..	..	×	×	×	?	..	..	..	×	..	..	..	Fusus curtus, *Jeff.* (G. J.).
—— gracilius, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Pleurotoma attenuata ? (S. W.).
—— islandicus, *Gmel.*	..	..	..	..	..	..	..	..	×	..	..	..	..	×				
—— Jeffreysianus, *Fischer*	..	..	..	..	..	..	×	..	×	..	..	..	..	×				
—— Krŏyeri ? *Möll.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×		
—— muricatus, *Mont.*	..	..	..	..	..	?	×	×	×	..	..	..	..	×				
—— Olavii, *Beck*	..	..	..	..	..	..	..	..	×	..	..	..	..	×				

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA.—*continued.*

	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-Bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	
Trophon propinquus, *Alder*	..	×	..	..	..	..	×	×	×	..	..	..	..	×				
——— pseudo-Turtoni, *S. Wood*	..	..	..	..	..	..	..	..	×	?	..	..	..	..	..	..	×	
——— Sarsii, *Jeff.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×		
——— scalariformis, *Gould*	..	..	..	..	..	..	×	..	×	×	..	×	..	..	..	×		
——— tortuosus, *L. Reeve*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×		
——— Turtoni, *Bean*	..	..	..	..	..	..	..	..	×	..	..	..	..	×				
——— vicinus, *Nyst*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
Turbo rugosus, *Linn.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
Turbonilla, see Odostomia.																		
Turritella incrassata, *J. Sow.*	..	×	..	×	×	×	×	×	×	×	..	..	..	..	×	..	..	T. triplicata, *Broc.* (S. W.). T. subangulata, *Broc.*
——— marginalis, *Broc.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
——— ? penepolaris, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— planispira, *S. Wood*	..	×	×	..	..	..	×	..	..	..	..	..	..	..	?	..	..	T. subangulata, *Broc.* (G. J.). T. incrassata, var. ? (C. R.).
——— taurinensis ? *Mich.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative (S. W.).
——— terebra, *Linn.*	..	..	..	..	..	×	..	..	?	×	×	×	..	×	..	..	..	T. communis, *Risso.*
Utriculus, see Bulla.																		
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
Velutina lævigata, *Pen.*	..	..	..	..	..	..	..	..	..	×	..	×	..	×				
——— undata, *J. Smith*	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	×		
——— virgata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	V. undata (G. J.).
Vermetus intortus, *Lam.*	..	×	..	..	..	..	×	×	×	..	..	..	..	..	×	..	..	V. subcancellatus, *Biv.* (S. W., G. J.).
——— ? triqueter, *Bivonæ*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	Perhaps annelids, Gen. Vermilia (S. W.).
Voluta Lamberti, *J. Sow.*	×	×	..	×	..	×	×	×	×	×	..	..	..	..	..	..	×	V. Junonia, *Ch.* ? (G. J.). V. Bolli, *Koch* ? (G. D.).
——— auris-leporis, *Grat.*	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Volvula, see Bulla.																		
Xenophorus, sp.	..	..	×	×	..	..	..	×	..	..	..	..	..	..	?	..	..	
Zaria, see Turritella.																		
Polyplacophora.																		
Chiton cancellatus, *J. Sow.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×				
——— discrepans ? *Brown*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— fascicularis, *Linn.*	..	×	..	..	..	×	..	..	..	..	..	..	..	×				
——— Hanleyi, *Bean*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— Rissoi, *Payr.*	..	×	..	..	..	..	..	.	..	..	..	..	..	..	×	..	..	C. cinereus, *Linn.* (G. J.).
——— squamosus, *Linn.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
Scaphopoda.																		
Dentalium bifissum, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	?			
——— dentalis, *Linn.*	×	×	?	×	..	..	×	×	×	..	..	..	..	..	×	..	..	D. costatum, Sow.
——— entalis, *Linn.*	..	×	..	×	..	..	..	..	×	..	..	..	..	×				

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-Bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	
Dentalium rectum, *Linn.*	..	..	..	..	..	..	×	..	×	..	..	..	..	..	×	..	..	Derivative? (S. W.).
——— semiclausum, *Nyst*	..	..	..	?	..	..	..	?	..	..	..	..	..	..	..	..	×	Horizon uncertain.
LAMELLIBRANCHIATA.																		
Abra alba, *W. Wood*	..	×	..	..	..	×	×	×	×	?	?	..	..	×				
—— fabalis, *S. Wood*	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×	A. alba, var.? (G. J.).
—— obovalis, *S. Wood*	..	..	..	..	..	..	..	..	×	×	..	..	..	..	?	..	..	Erycina ovata? (S. W.).
—— prismatica, *Mont.*	..	×	..	×	..	..	×	..	..	..	×	..	..	×				
Anomia ephippium, *Linn.*	..	×	..	×	..	×	..	×	×	×	×	..	..	×				
——— patelliformis, *Linn.*	..	×	..	..	..	..	×	..	×	×	×	..	..	×				
——— striata, *Broc.*	..	×	..	×	..	..	..	×	×	..	×	..	..	×				
Arca clathrata? *Defr.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	..	..	A. imbricata, *Poli* (G. D.).
—— diluvii, *Lam.*	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— lactea, *Linn.*	..	×	×	×	..	×	×	..	×	..	..	..	..	×				
—— pectunculoïdes, *Scac.*	..	×	..	×	..	..	..	..	..	..	..	..	..	×				
—— tetragona, *Poli*	..	×	..	..	..	×	..	..	×	..	..	..	..	×		..	..	A. imbricata, *Poli* (G. J.).
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
Artemis exoleta, *Linn.*	..	?	×	..	×	..	×	×	×	..	..	..	..	×		..	..	A. lentiformis, *J. Sow.* (G. J., Nyst).
——— lincta, *Pult.*	..	×	..	×	..	×	×	×	..	..	..	..	..	×				
Astarte Basteroti, *Laj.*	..	×	×	×	..	..	?	×	×	..	..	..	..	..	..	..	×	A. sulcata, var.? (G. J.)
——— borealis, *Chemn.*	..	..	..	..	..	..	..	..	..	×	×	×	?	..	..	×		
——— Burtini, *Laj.*	..	×	..	×	..	..	..	×	×	?	..	..	..	..	..	..	×	
——— compressa, *Mont.*	..	..	..	..	..	..	×	..	×	×	×	×	..	×				
——— corbuloides, *Laj.*	..	..	..	×	..	..	..	×	..	..	..	..	..	..	..	..	×	
——— crebricostata, *Forbes*	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	×		
——— crebrilirata, *S. Wood*	..	..	..	..	..	..	×	?	×	..	..	..	..	..	..	..	×	Crassina depressa, *Br.* (G. J.).
——— elliptica, *Brown*	..	..	..	..	..	..	..	?	..	?	..	×	..	×	..	..	..	A. sulcata, var. (G. J.).
——— Forbesii, *S. Wood*	..	×	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×	A. pusilla, *Forbes* (G. J.).
——— Galeottii, *Nyst*	..	×	×	×	..	..	×	×	×	..	..	..	..	..	..	..	×	A. compressa, *Mont.* (G. J.).
——— incerta, *S. Wood*	..	×	..	×	..	..	..	×	..	..	..	..	..	..	..	..	×	A. compressa, var. (G. J.).
——— incrassata, *Broc.*	..	×	..	..	..	..	..	×	×	..	..	..	..	..	×	..	..	A. sulcata, var. (G. J.). A. fusca, *Poli* (G. D.).
——— mutabilis, *S. Wood*	..	×	..	..	..	..	..	×	×	..	..	..	..	..	..	..	×	
——— obliquata, *J. Sow.*	..	..	..	×	..	..	×	×	×	..	..	..	..	..	..	..	×	A. Burtini, var. (G. J.).
——— Omalii, *Laj.*	..	×	×	×	..	×	..	×	×	?	..	..	..	..	..	..	×	A. undata, *Gould* (G. J.).
——— parvula, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	A. triangularis, var. (G. J.).
——— pygmæa, *Mont.*	..	×	..	×	..	×	..	×	..	..	..	..	..	..	..	..	×	A. Waelii, *Nyst* (G. J., G. D.).
——— sulcata, *Da C.*	..	..	..	..	..	..	..	..	×	?	×	×	..	×				
——— triangularis, *Mont.*	..	×	..	×	..	..	×	..	..	..	..	..	..	×	..	..	..	A. minuta, (G. J.). A. Waelii, *Hörnes* (G. D.).
——— trigonata, *Nyst*	..	×	..	?	..	..	..	..	..	..	..	..	..	..	..	..	×	Coralline Crag (*Nyst*).
Avicula phalænoides, *S. Wood*	..	×	?	..	..	..	..	..	..	..	..	..	..	..	..	..	×	A. hirundo, *Linn.* (G. J.).

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Axinus, see Cryptodon.																		
Bornia ovalis, *S. Wood*	..	×	..	..	..	..	..	..	..	.	..	..	..	..	..	..	×	
Cardita aculeata, *Poli*	..	..	..	..	×	×	..	..	..	..	..	..	..	..	×			
—— anceps, *S. Wood*	..	×	..	..	..	..	?	..	?	..	..	..	..	..	..	..	×	Derivative in Red Crag (S. W.).
—— calyculata, *Linn.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
—— chamæformis, *Leathes*	..	×	..	×	..	..	?	×	×	..	..	..	..	..	..	..	×	Derivative in Red Crag? (S. W.). C. scalaris. var. (G. J.).
—— corbis, *Phil.*	..	×	..	..	..	..	×	..	×	..	×	..	..	..	×			
—— orbicularis, *Leathes*	..	×	..	×	..	..	..	×	?	..	..	..	..	..	..	..	×	Derivative in Red Crag (S. W.).
—— scalaris, *Leathes*	..	×	..	×	..	..	×	×	×	?	?	..	..	..	..	..	..	C. venticosa, *Gould*? (S. W.).
—— senilis, *Lam.*	..	×	×	?	..	..	×	×	×	..	..	..	..	..	..	..	×	C. sulcata, *Brug.* (G. J.). Derivative in Red Crag? (S. W.).
Cardium angustatum, *J. Sow.*	..	..	..	..	..	..	..	..	×	×	..	..	..	..	..	..	×	C. edule, monstr.? (G. J.).
—— decorticatum, *S. Wood*	×	×	..	×	..	..	..	×	×	..	..	..	..	..	..	..	×	C. lævigatum, *Poli* (G. J.). C. norvegicum, var. (G. J.).
—— echinatum, *Linn.*	..	..	..	..	×	..	..	..	×	..	..	×	..	×				
—— edule, *Linn.*	..	×	..	..	..	..	×	×	×	×	×	×	×	×				
—— fasciatum, *Mont.*	..	×	..	×	..	..	×	..	×	..	×	..	..	×				
—— grœnlandicum, *Chemn.*	..	..	..	..	..	..	..	..	×	×	×	×	..	..	..	×		
	1.	2.	3.	4	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
——— interruptum, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	C. norvegicum (G. J.).
——— nodosum, *Turt.*	..	×	..	×	..	..	..	..	?	..	..	..	..	×				
——— papillosum, *Poli*	..	..	×	..	×	..	..	..	..	..	..	..	..	..	×			
——— Parkinsoni, *J. Sow.*	..	..	..	..	..	..	×	×	×	?	..	..	..	..	..	..	×	C. Nuttalii, *Conrad* (G. J.).
——— pinnatulum, *Con.*	..	..	..	..	..	..	×	..	×	..	..	..	..	..	..	..	..	Living, United States.
——— strigilliferum, *S. Wood*	..	×	..	..	×	×	×	..	..	..	..	..	..	..	..	..	×	C. elegantulum, *Möll.* (G. J.).
——— tuberculatum, *Linn.*	..	..	..	..	×	..	..	?	..	..	..	..	..	×				
——— venustum, *S. Wood*	..	..	..	..	..	..	×	..	×	..	..	..	..	..	..	..	×	C. decorticatum, var.? (S. W.). C. norvegicum, var. (G. J.).
——— n. sp.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	Allied to C. strigilliferum (C. R.).
——— n. sp.	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
Chama gryphoides, *Linn.*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	×	..	..	Derivative in Red Crag? (S. W.),
Circe minima, *Mont.*	..	×	..	×	..	..	×	×	×	..	..	..	..	×	..	..	..	Cythere trigona (G. J.). Derivative in Red Crag? (S.W.).
Cochlodesma complanatum, *S. Wood*	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	×	Thracia prætenuis, *Pult.* var. (G. J.).
——— prætenerum, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	T. prætenuis, (G. J.).
——— prætenue, *Pult.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
Coralliophaga cyprinoides, *S. Wood*	..	×	..	?	..	..	..	..	..	..	..	..	..	..	?	..	..	Chama lithophagella, *Broc.*? (S. W.).
Corbula contracta? *Say*	..	..	..	..	..	..	..	..	..	×	×	×	..	..	..	..	..	Living, North America.
——— gibba, *Olivi*	..	×	..	×	..	×	×	×	×	×	×	×	..	×	..	..	..	C. striata, *auct.*; Cardium striatum opicibus reflexis, *Walker & Boys* (C. R.).
——— ovata, *Forbes*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	..	..	C. mediterranea, *Wood* (G. D.).
Corbulomya complanata, *J. Sow.*	..	..	..	..	..	..	×	×	×	..	..	..	..	..	..	..	×	
Cryptodon rotundatum, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
——— sinuosum, *Don*	..	×	..	×	..	×	..	..	..	..	×	..	..	×	..	..	..	C. flexuosum, *Mont.*
Cucullæa, see Arca.																		

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Cultellus cultellatus, *S. Wood*	..	..	..	×	..	..	×	×	..	..	..	..	..	..	..	..	×	C. tenuis, *Phil.* ?
——— pellucidus, *Pen.*	..	..	..	..	..	×	..	..	..	..	×	..	..	×				
——— suttonensis, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Cyprina islandica, *Linn.*	×	×	×	×	..	..	?	×	×	×	×	×	?	×				
——— rustica, *J. Sow.*	×	×	..	×	..	..	..	×	×	..	..	..	..	..	..	..	×	
Cytherea Chione, *Linn.*	..	×	×	×	..	..	..	×	×	..	..	..	..	×	..	..	..	Derivative in Red Crag ? (S. W.).
——— rudis, *Poli*	..	×	..	×	..	..	×	×	×	?	..	..	..	..	×			
Diplodonta astartea, *Nyst*	..	×	?	×	..	..	..	×	×	×	..	..	..	..	?	..	..	Lucina trigonula, *Bronn* ? (S. W.).
——— dilatata, *S. Wood*	..	×	×	×	..	..	..	×	×	..	..	..	..	..	..	..	×	Not D. rotundata, var. dilatata of Philippi (S. W.). D. Woodi, *Nyst* (S. W.). D. rotundata var. (G. J.).
——— rotundata, *Mont.*	..	×	..	×	..	..	..	..	×	..	..	..	..	×				
Donax politus, *Poli*	..	×	×	..	..	..	×	×	×	..	..	..	..	×				
——— ? subfragilis, *D'Orb.*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
——— trunculus, *Linn.*	..	..	..	..	..	..	..	..	×	..	..	..	..	×				
——— vittatus, *Da C.*	..	..	..	..	..	..	..	..	?	×	..	×	×	×				
Erycinella ovalis ? *Conrad*	..	×	..	..	..	×	×											
Gastrana fragilis, *Linn.*	..	..	×	..	..	..	..	..	..	..	..	..	..	×				
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
—— laminosa, *Sow.*	..	×	..	..	..	..	×	×	×	..	..	..	..	..	?	..	..	Petricola ventricosa ? (S. W.). G. guinaica, *Chemn.* (G. J.).
Gastrochæna dubia, *Penn.*	..	×	..	?	..	..	..	..	×	..	..	..	..	×				
Glycimeris angusta, *Nyst*	×	×	..	×	..	..	..	×	×	..	..	..	..	..	..	..	×	G. siliqua (G. J.).
Hinnites Cortesyi, *De Fr.*	..	×	×	..	..	..	..	..	×	?	..	..	..	..	..	..	×	H. giganteus, *P. Carp.* (G. J.). Derivative in Red Crag (S. W.).
Hippagus, see Verticordia.																		
Isocardia Cor, *Linn.*	×	×	×	×	..	..	..	..	×	..	..	..	..	×	..	..	..	Derivative in Red Crag. ? (S. W.).
Kellia suborbicularis, *Mont.*	..	×	..	×	..	..	×	..	×	..	..	..	..	×				
——, see also Lasæa, Scintilla, and Scacchia.																		
Lasæa Clarkiæ, *Clark*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— intermedia, *S. Wood*	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	×	
—— pumila, *S. Wood*	..	×	..	?	..	×	..	..	..	..	..	..	..	..	..	..	×	Living, deep Atlantic (G. J.).
—— rubra, *Mont.*	..	×	..	..	×	×	..	..	..	..	..	..	..	×				
Leda lanceolata, *J. Sow.*	..	..	..	..	..	..	..	..	×	×	×	..	..	..	..	×		
—— minuta, *Mont.*	..	..	..	..	..	..	..	..	×	..	..	..	..	×				
—— myalis, *Couth.*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Leda-myalis Bed only—the Crag specimens are L. oblongoides (C. R.).
—— oblongoides, *S. Wood*	..	..	..	..	..	..	..	..	×	×	×	×	..	..	..	?	..	Not Leda-myalis (C. R.).
—— pella, *Linn.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
—— pygmæa, *Münst.*	..	×	..	×	..	..	×	..	..	..	..	..	..	×	..	..	..	L. tenuis, *Phil.* non L. pygmæa (Nyst).
—— semistriata, *S. Wood*	..	×	?	×	..	..	..	×	..	..	..	..	..	..	..	..	×	The Lenham specimens are quite smooth (C. R.).
—— Westendorpi, *Nyst*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
Lepton deltoideum, *S. Wood*	..	×	×	..	..	×	..	×	×	..	..	..	..	..	..	..	×	Erycina Geoffroyi, *Payr.* (G. J.).
—— depressum, *Nyst*	..	×	..	×	..	..	..	×	..	..	..	..	..	..	..	..	×	L. nitidum, *Turt.* (G. J.).

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Lepton nitidum, *Turt.*	..	×	..	..	×	..	..	..	..	×	×	..	..	×	..	..	..	L. squamosum, jun. (G. J.).
——— squamosum, *Mont.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
Lima elongata, *Forbes*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— exilis, *S. Wood*	..	×	..	..	..	?	×	?	×	..	..	..	..	..	..	..	×	L. inflata, *Lam.* (G. J.).
—— hians, *Gmel.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— Loscombii, *G. B. Sow.*	..	×	?	×	..	..	×	..	..	..	..	..	..	×				
—— ovata, *S. Wood*	..	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	Ostrea nivea, *Broc.* (G. J.).
—— plicatula, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	?	..	..	L. squamosa, jun.? (S. W.).
—— squamosa, *Lam.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
—— subauriculata, *Mont.*	..	×	..	×	..	..	..	..	..	..	..	..	..	×				
Limopsis aurita, *Broc.*	..	×	..	×	..	..	..	..	×	..	..	..	..	×				
——— pygmæa, *Phil.*	..	×	..	×	..	×	×	..	×	..	..	..	..	..	×	..	..	L. anomala, *D'Eich.*
Loripes divaricatus, *Linn.*	..	..	..	..	..	..	..	×	×	..	..	..	..	×				
Lucina borealis, *Linn.*	..	×	..	×	×	..	×	×	×	×	×	×	..	×				
——— crassidens, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative? (S.W.).
——— crenulata, *S. Wood*	..	×	..	..	..	..	..	?	..	..	..	..	..	..	..	..	×	
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
—— decorata *S. Wood*	..	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
Lucinopsis Lajonkairi, *Payr.*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative in Red Crag? (S. W.).
—— undata, *Pen.*	..	..	..	×	..	..	..	×	..	..	×	..	..	×				
Lutraria elliptica, *Lam.*	..	×	×	×	..	..	..	×	×	..	..	..	..	×	..	..	..	Derivative in Red Crag? (S. W.).
Lyonsia, sp.	..	×																
Mactra arcuata, *J. Sow.*	..	×	×	×	..	..	×	×	×	×	×	..	..	..	..	..	×	M. glauca, var. (G. J.).
—— artopta, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	M. glauca, var. (G. J.).
—— deaurata, *Turt.*	..	..	..	..	..	..	×	×	×	..	..	..	..	..	..	..	..	North America (S. W.). M. solida, monstr. (G. J.).
—— glauca, *Born.*	..	..	..	..	..	..	×	..	×	..	..	..	..	×				
—— ovalis, *J. Sow.*	..	..	..	..	..	×	..	×	×	×	×	×	..	×	..	..	..	M. solida, var. (G. J.).
—— ponderosa? *Phil.*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
—— procrassa, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	M. solidissima, *Ch.*; M. ponderosa, *Phil.* (G. J.).
—— solida, *Linn.*	..	×	..	..	×	..	×	×	×	×	×	..	..	×				
—— stultorum, *Linn.*	..	×	..	..	..	..	?	..	×	..	..	×	..	×				
—— subtruncata, *Da C.*	..	×	..	..	..	..	..	?	?	×	×	..	..	×				
—— triangula, *Ren.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	M. subtruncata (G. J.).
—— truncata, *Mont.*	..	..	..	..	..	..	×	..	×	..	..	..	..	×	..	..	..	M. solida, var. (G. J.).
Modiola barbata, *Linn.*	..	..	..	..	..	..	×	..	..	..	..	..	..	×				
—— costulata, *Risso*	..	×	..	..	..	..	×	..	..	..	..	..	..	×				
—— discors, *Linn.*	..	?	..	..	..	..	..	..	..	..	×	..	..	×				
—— marmorata, *Forbes*	..	×	..	..	..	..	×	..	..	..	..	..	..	×				
—— modiolus, *Linn.*	..	?	..	..	..	..	..	×	×	×	..	..	..	×				
—— Petagnæ, *Scac.*	..	×	..	..	..	..	×	..	..	..	..	..	..	..	×			

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

——	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	——
Modiola phaseolina, *Phil.*	..	×	..	×	..	..	..	..	..	..	..	..	..	×				
——— rhombea, *Berk.*	..	×	..	..	..	×	..	..	..	..	..	..	..	×	..	..	..	Crenella Pridauxi, *Leach.*
——— sericea, *Bronn*	..	×	..	×	..	..	..	×	..	..	..	..	..	..	..	..	×	
——— tulipa, *Lam.*	..	..	..	..	..	×	..	..	..	..	..	..	..	×				
Montacuta bidentata, *Mont.*	..	×	..	×	×	×	×	×	..	..	×	..	..	×				
——— elliptica. *S. Wood*	..	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×	
——— ferruginosa, *Mont.*	..	×	..	×	×	×	..	..	..	..	×	..	..	×				
——— truncata, *S. Wood*	..	×	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	M. bidentata, var. (G. J.).
———, see also Sphenalia.																		
Mya arenaria, *Linn.*	..	..	..	..	×	..	×	×	×	×	×	×	?	×				
—— truncata, *Linn.*	..	×	..	×	..	..	..	×	×	×	×	×	×	×				
Mytilus edulis, *Linn.*	..	×	..	..	..	×	×	×	×	×	×	×	×	×				
Neæra cuspidata, *Olivi*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— jugosa, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Deep Atlantic—N. lamellosa, *Sars* (G. J.).
——— obesa, *Lovén*	..	×	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	Deep Atlantic and Scandinavia (G. J.).
——— rostrata, *Spengl.*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
Nucinella ovalis, *S. Wood*	..	×	..	×	..	×	..	..	..	..	..	..	..	..	..	..	×	Not N. Miliaris (G. D.).
Nucula Cobboldiæ, *J. Sow.*	..	..	..	×	..	..	?	..	×	×	×	×	×	..	..	..	×	Diestian at Utrecht. N. insignis (G. J.).
——— lævigata, *J. Sow.*	..	×	..	×	..	×	×	×	×	..	..	..	..	..	..	..	×	
——— nitida, *G. Sow.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— nucleus, *Linn.*	..	×	..	×	×	×	×	×	×	..	..	..	..	×				
——— proxima, *Say*	..	×	..	..	?	..	..	..	..	..	..	..	..	..	..	..	..	Living, North America.
——— sulcata, *Bronn*	..	..	×	..	?	..	..	..	..	..	..	..	..	×				
——— tenuis, *Mont.*	..	?	..	..	..	..	?	×	×	×	×	..	..	×				
——— turgens, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative? (S. W.).
Ostrea cochlear, *Poli*	..	×	..	..	..	..	..	..	×	..	..	..	..	×				
——— edulis, *Linn.*	..	..	..	×	×	..	×	×	×	×	..	..	..	×	..	..	..	O. ungulata, *Nyst.*
——— plicatula, *Gmel.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
——— princeps, *S. Wood*	..	×	×	×	..	..	..	×	×	..	..	..	..	..	..	..	×	Derivative in Red Crag (S. W.).
Pandora inequivalvis, *Linn.*	..	×	..	..	..	..	×	..	×	..	..	..	..	×				
Panopæa Faujasii, *Men. de la G.*	×	×	..	×	..	..	..	×	×	..	..	..	..	..	×	..	..	P. glycimeris, *Born.*; P. Aldrovandi, *Phil.* (S. W.).
——— ? plicata, *Mont.*	..	×	..	?	..	×	..	?	..	..	..	..	..	×	..	..	..	Saxicava ? fragilis, *Wood* non *Nyst.*
——— ? norvegica, *Speng.*	..	..	..	..	..	..	..	..	×	×	×	..	..	×				
Pecten Bruei, *Payr.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
——— disparatus, *S. Wood*	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	Derivative? (S. W.).
——— dubius, *Broc.*	..	×	..	×	..	..	×	×	×	..	..	..	..	..	..	..	×	P. radians, *Nyst.*
——— Gerardii, *Nyst*	..	×	..	×	..	..	..	×	..	..	..	..	..	..	..	..	×	P. grœnlandicus, *Chem.* (G. J.).
——— grandis, *J. Sow.*	..	×	..	×	..	..	..	?	×	..	..	..	..	..	..	..	×	Derivative in Red Crag ? (S. W.). P. maximus, var.
——— maximus, *Linn.*	..	×	×	?	×	..	..	×	×	..	..	..	..	×				

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Pecten niveus ? *McGill*	..	?	..	..	..	..	..	..	..	..	..	..	..	×				
—— opercularis, *Linn.*	×	×	..	×	×	..	×	×	×	×	×	?	..	×				
—— princeps, *J. Sow.*	..	×	×	×	..	..	..	..	..	×	..	..	..	..	..	..	×	P. islandicus, *Chem.* (G. J.).
—— pusio. *Pen.*	..	×	..	?	..	×	×	×	×	?	..	..	..	×				
—— septemradiatus, *Chem.*	..	..	..	..	..	..	..	×	×	..	..	..	..	×				
—— similis, *Lask.*	..	×	..	×	..	×	..	..	..	..	..	..	..	×				
—— tigrinus, *Müll.*	..	×	..	×	..	..	×	×	×	?	×	..	..	×	..	..	..	P. anicus (G. J.).
—— varius, *Linn.*	..	?	×	..	..	..	..	..	..	..	..	..	..	×				
—— westendorpianus, *Nyst*	..	..	..	×	..	..	..	..	×	..	..	..	..	..	..	..	×	
—— n. sp.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— n. sp.	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Pectunculus glycimeris, *Linn.*	×	×	×	×	×	×	×	×	×	×	×	..	..	×	..	..	..	Including var. subobliquus.
—— pilosus, *Linn.*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	×			
Pholadidea papyracea, *Sol.*	..	×	×	..	..	..	..	..	..	..	..	..	..	×				
Pholadomya hesterna, *J. Sow.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
Pholas candida, *Linn.*	..	..	..	..	..	..	..	..	..	×	..	..	..	×				
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
—— crispata, *Linn.*	..	..	..	..	..	..	×	..	×	..	..	×	×	×				
—— cylindrica, *J. Sow.*	..	..	..	..	..	..	×	..	×	..	..	..	..	..	..	..	×	Not P. dactylus (S. W.).
—— intermedia, *S. Wood*	..	×	..	..	..	..	..	..	×	..	..	..	..	..	..	..	×	
—— parva, *Pen.*	..	..	..	..	..	×	..	?	×	..	..	..	..	×				
Pinna pectinata ? *Mont.*	..	×	..	×	..	..	?	×	×	..	..	..	..	×	..	..	..	P. rudis (G. J.).
—— rudis ? *Linn.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
Poromya granulata, *Nyst*	..	×	..	×	..	×	..	..	..	..	..	..	..	×				
Psammobia costulata, *Turt.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— ferroensis, *Chem.*	..	×	..	×	..	..	..	×	..	..	..	..	..	×				
—— tellinella, *Linn.*	..	×	..	..	..	..	..	..	..	..	..	..	..	×				
—— vespertina, *Chem.*	..	×	..	..	..	..	..	×	..	..	..	..	..	×				
Saxicava carinata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	Panopæa plicata, var. (G. J.).
—— *fragilis*, see Panopæa.																		
—— rugosa, *Linn.*	..	×	..	×	..	×	×	×	×	×	×	×	..	×				
Scacchia cycladia, *S. Wood*	..	×	..	?	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— elliptica, *Phil.*	..	×	..	?	..	..	..	..	..	..	..	..	..	..	×			
—— ata, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	
—— orbicularis, *S. Wood*	..	×	..	?	..	..	..	..	..	..	..	..	..	×	..	..	..	S. cycladia, var. (G. J.).
Scintilla ambigua, *Nyst*	..	×	..	×	..	..	×	×	×	..	×	..	..	..	..	..	×	
—— compressa, *Phil.*	..	×	..	×	..	..	..	×	..	..	..	..	..	..	×	..	..	Kellia coarctata.
Scrobicularia plana, *Da C.*	..	..	..	..	..	..	..	..	×	×	×	×	..	×				
Semele, see Abra.																		
Siliquaria parva, *Speyer*	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	×	Derivative ? (S. W.).

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TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

—	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-Bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.	—
Solecurtus coarctatus, *Gmel.*	..	..	..	..	..	..	..	×	..	..	..	..	..	×				
——— strigillatus, *Linn.*	..	×	..	..	..	..	..	×	?	..	..	..	..	..	×	..	..	S. candidus (S. W.).
Solen ensis, *Linn.*	..	×	×	×	×	..	×	×	×	..	?	..	..	×				
—— gladiolus, *Gray*	..	..	..	..	..	..	×	×	×	..	..	..	..	..	..	×	..	S. siliqua, var. (G. J.).
—— siliqua, *Linn.*	..	..	..	..	..	..	..	..	×	×	?	..	..	×				
Sphenalia donacina, *S. Wood*	..	×	..	?	..	..	..	..	..	..	..	..	..	×				
——— substriata, *Mont.*	..	×	..	?	..	..	..	..	..	..	×	..	..	×				
Sphenia Binghami, *Turt.*	..	..	..	×	×	..	×	×	×	..	..	..	..	×	..	..	..	Saxicava fragilis, *Nyst* non *Wood.*
——— ovata ? *Carp.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Living, America ?
Tapes aureus, *Gmel.*	..	..	..	..	×	..	..	..	..	×	..	..	..	×				
—— decussatus, *Linn.*	..	..	..	..	..	..	..	..	..	..	..	×	..	×				
—— perovalis, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×	T. virgineus, var. (G. J.).
—— pullastra, *Mont.*	..	?	..	..	×	..	?	..	×	..	..	..	..	×				
—— striatella, *Nyst*	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×	
—— texturatus, *Lam.*	..	..	..	..	..	..	×	..	×	..	..	..	..	×	..	..	..	T. aureus, *Gmel.* (G. J.).
—— virgineus, *Linn.*	..	×	..	..	×	..	×	×	×	×	..	..	..	×				
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	
Tellina balaustina, *Linn.*	..	×	..	×	..	..	..	?	..	..	..	..	..	×				
——— balthica *Linn.*	..	..	..	..	..	..	..	..	..	..	..	×	×	×				
——— Benedeni, *Nyst*	..	..	×	×	..	..	..	×	×	..	..	..	..	..	..	..	×	T. calcaria, var. (G. J.).
——— calcaria, *Chem.*	..	..	..	..	..	..	..	..	×	×	×	×	..	×	..	..	..	Tellina lata, *Gmel.*
——— compressa, *Broc.*	..	×	..	×	..	..	..	×	..	..	..	..	..	..	×			
——— crassa, *Gmel.*	..	×	..	..	..	..	×	×	×	×	×	..	..	×				
——— donacina, *Linn.*	..	×	×	..	..	..	..	×	×	..	..	..	..	×				
——— fabula, *Gronov.*	..	..	..	..	..	..	..	..	..	×	×	..	..	×				
——— obliqua, *J. Sow.*	..	×	..	..	..	..	×	×	×	×	×	×	×	..	..	..	×	T. calcaria, var. (G. J.).
——— prætenuis, *Leathes*	..	..	..	..	..	..	?	×	×	×	×	×	..	..	..	..	×	T. calcaria, var. (G. J.).
——— pulchella ? *Lam.*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	×			
——— serrata, *Broc.*	..	..	..	..	..	×	..	..	..	..	..	..	..	..	×			
Teredo norvegica, *Speng.*	..	×	..	×	..	..	..	..	×	..	..	..	..	×				
Thracia distorta ? *Mont.*	..	?	..	?	..	..	..	..	..	..	..	..	..	×				
——— inflata, *J. Sow.*	..	×	..	×	..	..	..	..	?	..	..	..	..	..	..	..	×	T. corbuloïdes, *Desh.* var. (G. J.).
——— papyracea, *Poli*	..	×	..	..	..	..	..	×	..	×	×	×	..	×	..	..	..	Belaugh (S. W.).
——— pubescens, *Pult.*	..	×	×	×	..	..	..	×	..	..	..	..	..	×				
——— ventricosa, *Phil.*	..	×	×	..	..	..	..	×	..	..	..	..	..	..	..	..	×	T. convexa, *W. Wood* (G. J.).
Venerupis Irus, *Linn.*	..	×	..	..	..	×	×	..	..	..	..	..	..	×				
Venus casina, *Linn.*	..	×	..	×	..	..	..	×	×	..	..	..	..	×				
——— fasciata, *Da C.*	..	..	..	..	..	..	×	..	×	×	..	..	..	×				
——— imbricata, *J. Sow.*	..	×	..	×	..	..	×	×	×	..	..	..	..	..	..	..	×	V. fasciata, var. (G. J.).
——— ovata, *Pen.*	..	×	..	×	..	..	..	×	×	..	×	..	..	×				

TABLE VII.—MARINE MOLLUSCA OF THE NORTH EUROPEAN PLIOCENE STRATA—*continued.*

	Box Stones.	Coralline Crag.	Lenham Beds.	Diestian.	St. Erth.	Normandy.	Walton Crag.	Scaldisian.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.	Living—British.	Living—Southern.	Living—Northern.	Extinct.
Verticordia cardiiformis, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×
Woodia digitaria, *Linn.*	..	×	..	×	..	×	×	×	×	..	..	..	..	×			
——— excurrens, *S. Wood*	..	×	..	×	..	×	..	..	..	..	..	..	..	..	..	..	×
Yoldia, see Leda.																	
BRACHIOPODA.																	
Argiope cistellula, *S. Wood*	..	×	..	×	..	..	..	..	..	..	..	..	..	×			
——— n. sp.	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	×
Discina fallens, *S. Wood*	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	×
Lingula Dumortieri, *Nyst*	..	×	..	×	..	×	..	×	..	..	..	..	..	..	..	..	×
Rhynchonella Nystii, *Davids.*	..	..	..	..	..	..	..	?	..	..	..	..	..	..	..	..	×
——— psittacea, *Chem.*	..	..	..	..	..	..	..	?	×	×	×	×	..	×			
Terebratula grandis, *Blum.*	..	×	×	×	..	×	×	..	×	..	..	..	..	..	..	..	×
Terebratulina caput-serpentis, *Linn.*	..	×	..	×	..	×	..	..	..	..	..	..	..	×			

TABLE VIII.—POLYZOA (BRYOZOA).

Authorities :—Busk's "Crag Polyzoa," Palæont. Soc. A. and R. Bell, "On the English Crags," *Proc. Geol. Assoc.*, Vol. II., pp. 185–218, 270–272. Hincks, "British Marine Polyzoa."

	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Living, British.	Living, Southern.	Extinct.	
Alecto dilatans, *Johnst.*	×	×	..	..	..	×			
—— repens, *S. Wood*	×	×	..	..	..	×			
Alveolaria semiovata, *Busk*	×	×	..	..	×	..	..	×	
Alysidota catena, *S. Wood*	×	..	..	..	..	..	..	×	
—— labrosa, *Busk*	..	×	..	..	..	×			
Biflustra delicatula, *Busk*	×	×	..	..	..	..	×	..	Australia, &c.
Cellepora cespitosa, *Busk*	×	×	..	..	..	..	..	×	
—— compressa, *Busk*	×	×	×	..	..	..	..	×	
—— coronopus, *S. Wood*	×	..	..	..	..	..	..	×	
—— dentata, *Busk*	×	..	..	..	..	..	..	×	
—— echinata, *Michel.*	×	..	..	..	..	..	..	×	
—— edax, *Busk*	×	×	..	..	..	×			
—— parasitica, *Michel.*	×	×	..	..	..	..	..	×	Faluns.
—— ramulosa, *Linn.*	×	..	..	..	..	×			
—— scruposa, *Busk*	×	×	..	..	..	..	..	×	
—— tubigera, *Busk*	×	..	..	..	..	×			
Crisia denticulata ? *Lam.*	×	..	..	..	..	×	..	..	Also Gourbesville.
Cupularia canariensis, *Busk*	×	..	..	..	..	..	×	..	Also Lenham Beds.
—— denticulata, *Conrad*	×	..	..	..	..	..	×		
—— porosa, *Busk*	×	..	..	..	..	..	..	×	
Defrancia rugosa, *Busk*	×	×	..	..	..	..	..	×	Also Gourbesville.
—— striatula, *Busk*	×	..	..	..	..	..	..	×	
Diastopora simplex, *Busk*	×	×	..	..	..	×			
Discoporella grignonensis, *M. Edw.*	×	×	..	..	..	..	..	×	
—— hispida ? *Johnst.*	×	×	..	..	..	×			
Eschara cornuta, *Busk*	×	..	..	..	..	..	..	×	
—— incisa, *M. Edw.*	×	..	..	..	..	..	..	×	Faluns.
—— monilifera, *M. Edw.*	×	×	..	..	..	..	..	×	Faluns.
—— pertusa, *M. Edw.*	×	..	..	..	..	..	..	×	Faluns.
—— porosa, *M. Edw.*	×	×	..	..	..	..	..	×	Italian Pliocene.
—— Sedgwickii, *M. Edw.*	×	×	..	..	..	..	..	×	Faluns.
—— sinuosa, *Busk*	×	×	×	..	..	..	..	×	
—— socialis, *Busk*	×	..	..	..	..	..	..	×	
Fascicularia aurantium, *M. Edw.*	×	×	..	..	..	..	..	×	Also Lenham Beds.
—— tubipora, *Busk*	×	×	?	..	..	..	..	×	

TABLE VIII.—*continued.*

—	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Living, British.	Living, Southern.	Extinct.	—
Flustra dubia, *Busk*	×	..	..	..	..	..	..	×	
Fungella infundibulata, *Busk*	×	..	..	..	..	..	..	×	
——— multifida, *Busk*	×	..	×	..	..	..	..	×	
——— quadriceps, *Busk*	×	..	..	..	..	..	..	×	
Hemeschara imbellis, *Busk*	×	×	..	..	..	..	..	×	
Heteropora clavata, *Goldf.*	×	..	..	..	..	..	..	×	
——— lævigata, *D'Orb.*	×	..	..	..	..	..	..	×	Cretaceous.
——— pustulosa, *Busk*	×	×	×	..	..	..	..	×	
——— reticulata, *Busk*	×	..	..	..	..	..	..	×	
Heteroporella parasitica, *Busk*	×	..	..	..	..	..	..	×	
——— radiata, *Busk*	×	×	..	..	..	..	..	×	
Hippothoa abstersa, *S. Wood*	×	×	×	..	..	..	..	×	
——— dentata, *S. Wood*	×	..	..	..	..	..	..	×	
——— patagonica, *Busk*	×	..	..	..	..	×			
Hornera canaliculata, *Busk*	×	..	..	..	..	..	..	×	
——— frondiculata, *Lamour.*	×	×	..	..	..	..	×	..	Also Gourbesville.
——— hippolyta ? *Defr.*	×	..	..	..	..	..	..	×	Faluns.
——— humilis, *Busk*	×	..	..	..	..	..	..	×	
——— infundibulata, *Busk*	×	×	×	..	..	..	..	×	Faluns.
——— lunata, *Busk*	×	..	..	..	..	..	..	×	
——— pertusa, *Busk*	×	..	..	..	..	..	..	×	
——— reteporacea, *M. Edw.*	×	..	..	..	..	..	..	×	Faluns.
——— rhipis, *Busk*	×	..	..	..	..	..	..	×	
——— rhomboidalis, *Busk*	×	×	..	..	..	..	..	×	
——— striata, *M. Edw.*	×	×	..	..	..	..	..	×	Faluns.
Idmonea delicatula, *Busk*	×	..	..	..	..	..	..	×	
——— fenestrata, *Busk*	×	..	..	..	..	..	..	×	
——— intricaria, *Busk*	×	..	..	..	..	..	..	×	
——— punctata, *D'Orb.*	×	..	..	..	..	..	..	×	Cretaceous.
Lepralia ansata, *Johnst.*	×	×	..	..	..	×			
——— biaperta, *Michel.*	×	..	..	..	..	?	..	..	Arctic and Florida.
——— bicornis, *Busk*	×	..	..	..	..	×			
——— bowerbankiana, *Busk*	×	..	..	..	..	..	..	×	
——— Brongniartii, *Aud.*	×	..	..	..	..	×			
——— ciliata, *Linn.*	×	..	..	..	..	×			
——— figularis, *Johnst.*	×	..	..	..	..	×			
——— haimeseana, *Busk*	×	..	..	..	..	..	..	×	

TABLE VIII.—*continued.*

—	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Living, British.	Living, Southern.	Extinct.	—
Lepralia hyalina, *Linn.*	×	..	×	..	..	×			
——— infundibulata, *Busk*	..	×	..	..	..	..	..	×	
——— innominata, *Couch*	×	..	×	..	..	×			
——— lobata, *Busk*	×	×	..	..	..	..	..	×	
——— Malusii, *Aud.*	×	..	..	..	..	×			
——— mamillata, *S. Wood*	×	..	..	..	..	×			
——— megastoma, *S. Wood*	×	..	..	..	..	..	..	×	
——— milneana, *Busk*	×	..	..	..	..	..	..	×	
——— morrisiana, *Busk*	×	..	..	..	..	?			
——— pallasiana, *Moll.*	×	..	..	..	..	×	..	..	Also St. Erth.
——— papillata, *Busk*	×	..	..	..	..	..	..	×	
——— Peachii, *Johnst.*	×	×	..	..	..	×			
——— plagiopora, *Busk*	×	..	..	..	..	..	..	×	
——— punctata, *Hassall*	×	..	×	..	..	×			
——— puncturata, *S. Wood*	..	×	..	..	..	..	..	×	
——— pyriformis, *S. Wood*	×	..	..	..	..	..	..	×	
——— reussiana, *Busk*	×	..	..	..	..	..	..	×	
——— unicornis, *Johnst.*	×	×	..	..	..	×			
——— variolosa, *Johnst.*	×	..	..	..	..	×			
——— ventricosa, *Hassall*	×	..	..	..	..	×			
——— violacea, *Johnst.*	×	×	..	..	..	×	..	..	Also St. Erth.
——— woodiana, *Busk*	×	..	..	..	..	×			
Lunulites conica, *Defr.*	×	×	×	..	..	..	..	×	Faluns.
Melicerita Charlesworthii, *M. Edw.*	×	×	..	..	..	..	..	×	Faluns and St. Erth.
Membranipora andagavensis, *Mich.*	×	..	..	..	..	×			M. Smittii.
——— aperta, *Busk*	×	..	..	..	..	..	..	×	
——— bidens, *Hag.*	×	..	..	..	..	..	..	×	Chalk
——— catenularia, *Jameson*	×	..	×	..	..	×			
——— dubia, *Busk*	×	×	..	..	..	..	..	×	
——— fissurata, *Busk*	×	..	..	..	..	..	..	×	
——— nolostoma, *S. Wood*	×	..	..	..	..	.	..	×	
——— Lacroixii, *Aud.*	×	..	×	..	..	..	..	×	
——— monostachys, *Busk*	..	×	×	..	×	×			
——— oblonga, *Busk*	×	×	..	..	..	..	..	×	
——— oceani, *D'Orb.*	×	..	..	..	..	..	..	×	Cretaceous.
——— Pouilletii, *Aud.*	×	×	..	..	..	×			
——— rynchota, *Busk*	×	..	×	..	..	..	..	×	
——— Savartii, *Aud.*	..	×	×	..	..	..	×		

TABLE VIII.—*continued.*

	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Living, British.	Living, Southern.	Extinct.	
Membranipora trifolium, *S. Wood*	×	×	×	..	..	×			
——— tuberculata ? *Bosc.*	×	×	×	..	..	..	×	..	Living on Sargassum.
Mesenteripora meandrina, *S. Wood*	×	..	..	..	..	..	..	×	
Multizonopora ramulosa. *D'Orb.*	×	..	..	..	..	..	..	×	
Patinella proligera, *Busk*	×	..	..	..	..	..	..	×	Also Gourbesville.
Pustulopora clavata, *Busk*	×	..	..	..	..	×			
——— palmata, *Busk*	×	..	..	..	..	..	..	×	
——— subverticellata, *Busk*	×	..	..	..	..	..	..	×	
Reptomulticava macropora, *D'Orb.*	..	×	..	..	..	..	..	×	
Retepora beaniana, *King*	×	..	?	..	..	×			
——— cellulosa, *Linn.*	×	..	..	..	..	×			
——— notopachys, *Busk*	×	..	..	..	..	..	..	×	
——— simplex, *Busk*	×	×	..	..	..	..	..	×	
Salicornaria crassa, *S. Wood*	×	×	..	..	×	..	..	×	
——— sinuosa, *Hassall*	×	×	×	..	..	×	..	..	Also St. Erth.
Scrupocellaria scruposa ? *Linn.*	×	..	..	..	..	×			
Tubulipora flabellaris, *Johnst.*	×	×	..	..	..	×			
——— phalangea, *Couch*	×	×	..	..	..	×			

TABLE IX.—MARINE CRUSTACEA.

	Coralline Crag.	Walton Crag.	St. Erth Beds.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.
Acasta undulata, *Darw.*	×							
Atelecyclus, sp.	×							
Balanus bisulcatus, *Darw.*	×							
——— calceolus, *Pallas*	×							
——— concavus, *Bronn*	×	×	..	×				
——— crenatus, *Brag.*	×	×	..	×	×	×	×	×
——— dolosus, *Darw.*	.	×	..	×	×			
——— Hameri, *Asc.*	..	×	..	×	×	..	×	
——— inclusus, *Darw.*	×	×						
——— porcatus, *Da C.*	..	×	..	×	×	×	×	×

TABLE IX.—*continued.*

	Coralline Crag.	Walton Crag.	St. Erth Beds.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.
Balanus spongicola, *Brown*	×							
——— tintinnabulum, *Linn.*	..	×	..	×				
Cancer pagurus, *Linn.*	×	×	..	×				
Carcinus mænas, *Linn.*	×	×	..	×	×			
Coronula barbara, *Darw.*	..	×	..	×				
Ebalia Bryerii, *Leach*	×							
Gonoplax angulata, *Leach*	×							
Maia squinado, *Leach*	×							
Pagurus Bernhardus, *Fabr.*	×							
Portunus puber, *Linn.*	×							
——— depurator, *Leach*	×							
Pyrgoma anglicum, *G. B. Sow.*	×							
Scalpellum magnum, *S. Wood*	×							
Verruca Strömia, *Müll.*	×	×						
(Ostracoda.)								
Aglaia? cypridoides, *J. & S.*	..	..	..	..	×			
Bairdia fusca? *Brady*	×							
——— rhomboidea, *J. & S.*	×							
——— sp.	..	..	..	×				
Cythere angulata, Sars.	..	..	..	..	×	..	×	
——— baccata, *J. & S.*	..	..	..	..	×	..	×	
——— Charlesworthiana, *J. & S.*	..	..	..	..	..	..	×	
——— convexa, *Baird*	×							
——— dictyosigma, *Jones*	×							
——— lachrymalis, *J. & S.*	..	..	..	..	×			
——— læsa, *J. & S.*	..	..	..	..	×			
——— laqueata, *Jones*	×	..	..	×	..	..	×	
——— latimarginata, *Speyer*	×							
——— macropora, *Jones*	×							
——— polyptycha, *Reuss*	..	..	..	..	×			
——— recurata, *J. & S.*	..	..	..	..	×			
——— Reidii, *J. & S.*	..	..	..	.	..	..	×	
——— retifastigiata, *Jones*	..	..	..	..	..	..	×	
——— sublacunosa, *Jones*	×							
——— trachypora, *Jones*	×	..	..	×	×			
——— trigonula, *Jones*	×							
——— villosa, *Sars.*	..	..	..	..	×	..	×	

TABLE IX.—*continued.*

	Coralline Crag.	Walton Crag.	St. Erth Beds.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	Forest-bed.
Cythere Woodiana, *Jones*	×							
——— Woodwardiana, *J. & S.*	..	..	..	..	..	..	×	
Cythereis Hoernesi, *Speyer*	×							
——— Jonesii, *Baird*	×							
——— senilis, *Jones*	×							
Cytherella sp.	..	..	..	..	..	..	×	
Cytheridea elongata, *Brady*	..	..	..	..	×	..	×	
——— pinguis, *Jones*	×	..	..	..	..	..	×	
——— punctillata, *Brady*	..	..	..	..	×			
——— torosa, *Jones*	..	..	..	..	..	..	..	×
Cytherideis botellina, *Jones*	×							
——— ren, *Jones*	×							
Cytherura clathrata, *Sars*	..	..	..	..	..	..	×	
Loxoconcha tamarindus, *Jones*	×							
Potamocypris trigonalis, *Jones*	..	..	..	..	×	..	×	
——— tuberculata, *Jones*	×	×						

TABLE X.—ANNELIDS.

(Authorities:—A. & R. Bell, and S. V. Wood.)

	Lenham Beds.	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.
Cyclogyra multiplex, S. Wood	..	×					
Ditrupa gadus, Mont.	..	×	×	×			
——— subulata, Berk.	×	×					
Sabellaria conchilega, Phil.	..	..	..	×	..	×	
Serpula triquetra, Linn.	..	×	×				
——— vermicularis, Linn.	..	×	×	..	..	×	
Spirorbis carinatus, Mont.	..	×	×				
——— granulatus, Mont.	..	×					
——— heterostrophus, Mont.	..	×					
——— nautiloides ? Lam.	..	×					
——— sinistrorsus, Mont.	..	×					
——— supraplana, S. Wood	..	×					
Vermilia tricuspidata, Sow.	..	×					

TABLE XI.—ECHINODERMATA.

Authorities:—E. Forbes, "Tertiary Echinodermata"; A. & R. Bell.

——	Coralline Crag.	Lenham Crag.	St. Erth Beds.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	——
Amphidetus cordatus, *Pen.*	×								
Brissus Scillæ, *Ag.*	×								
Comatula Brownii, *Forbes*	×								
—— Ransomi, *Forbes*	×								
—— Woodwardi, *Forbes*	×								
Cucumaria, sp.	..	..	×	..	..	..	..	..	Kendall & Bell.
Echinarachinus? Woodii, *Forbes*	..	..	..	×					
Echinocyamus hispidulus, *Forbes*	×	..	..	×					
—— oviformis, *Forbes*	×	..	..	×					
—— pusillus, *Müll.*	..	..	..	×	×	×	×		
—— suffolciensis, *Ag.*	..	..	..	×	..	×			
Echinus Charlesworthii, *Forbes*	×								
—— Henslovii, *Forbes*	..	..	..	×					
—— Lamarckii, *Forbes*	×								
—— lividus, *Mull.*	..	..	..	..	..	..	×	..	E. sphæra?
—— Lyellii, *Forbes*	×								
—— Melo? *Lam.*	×								
—— miliaris, *Leske*	..	..	..	×					
—— Woodwardi, *Desor.*	×	..	..	×					
Spatangus purpureus, *Müll.*	×	..	..	..	×	..	×		
—— regina, *Gray*	×	..	..	..	×				
Temnechinus excavatus, *S. Wood*	×	..	..	×	×				
—— globosus, *Forbes*	×								
—— melocactus, *Forbes*	×								
—— turbinatus, *Forbes*	..	..	..	×	×				
Toxopneustes dröbachiensis, *Müll.*	..	..	..	..	×				
Uraster rubens, *Retz.*	..	..	..	×	×				
—— sp.	..	..	..	×					

Table XII.—Actinozoa.

——	Coralline Crag.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	——
Balanophyllia calyculus, *Wood*	..	×	×			
Cryptangia Woodii, *E. & H.*	×	×				
Flabellum Woodii, *E. & H.*	×					
Solenastrea Prestwichii, *Dunc.*	..	×	..	..	..	Derivative?
Sphenotrochus intermedius, *Munst.*	×	×	×			
——— boytonensis, Tomes	×	×	×			
——— n. sp.?	..	..	..	..	×	
Trococyathus anglicus, *Dunc.*	..	..	×			

Table XIII.—Foraminifera.

Authorities:—Jones, Parker, and Brady, "Crag Foraminifera"; T. W. Millett, Foraminifera of the St. Erth Clay.

——	Coralline Crag.	St. Erth.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	——
Alveolina, sp.	×							
Amphistegina vulgaris, *D'Orb.*	×							
Bigenerina nodosaria, *D'Orb.*	..	×						
Biloculina depressa, *D'Orb.*	×							
——— elongata, *D'Orb.*	..	..	×					
——— ringens, *Lam.*	×	×	×					
Bolivina dilatata, *Reuss*	..	×						
——— lævigata, *Will.*	..	×						
——— plicata, *D'Orb.*	..	×						
——— punctata, *D'Orb.*	×	×						
——— robusta, *Brady*	..	×						
——— textilariodes, *Reuss*	..	×						
Bulimina aculeata, *D'Orb.*	..	..	..	..	×			
——— affinis, *D'Orb.*	..	×						

TABLE XIII.—*continued.*

	Coralline Crag.	St. Erth Beds.	Walton Crag.	Red Crag	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	
Bulimina elegans, *D'Orb.*	..	..	..	..	..	×		
—— elegantissima, *D'Orb.*	..	×						
—— marginata, *D'Orb.*	×	×						
—— pupoides, *D'Orb.*	..	×						
Calcarina rarispina, *D'Orb.*	×	..	×					
Cassidulina Bradyi, *Norm.*	..	×						
—— crassa, *D'Orb.*	×	×						
—— lævigata, *D'Orb.*	×	×						
—— oblonga, *D'Orb.*	×	×						
Cornuspira foliacea, *Phil.*	×	×						
—— involvens, *Reuss.*	×	×						
Cristellaria crepidula, *F. & M.*	..	×						
—— cultrata, *Montag.*	×							
—— rotulata, *Lam.*	..	×						
Dendritina arbuscula, *D'Orb.*	×							
Dentalina obliqua, *Linn.*	×							
—— obliquestriata, *Reuss*	×							
—— pauperata, *D'Orb.*	×							
Dimorphina nodosaria, *Reuss*	×							
—— tuberosa, *D'Orb.*	×							
Discorbina globularis, *D'Orb.*	..	×						
—— orbicularis, *Terq.*	..	×						
—— patelliformis, *Brady*	..	×						
—— parisiensis, *D'Orb.*	..	×	×					
—— rosacea, *D'Orb.*	..	×	..	..	×			
—— turbo, *D'Orb.*	..	×						
—— Wrightii, *Brady*	..	×						
Faujasina carinata, *D'Orb.*	..	×						
Glandulina lævigata, *D'Orb.*	×	×						
Globigerina bulloides, *D'Orb.*	×	×	..	..	×			
—— cretacea, *D'Orb.*	..	×						
Lagena acuta, *Reuss*	..	×						
—— apiculata, *Reuss*	×	×						
—— bicarinata, *Terq*	..	×						
—— clavata, *D'Orb.*	..	×						
—— globosa, *Mont.*	×	×						
—— gracillima, *Seg.*	×	×						

TABLE XIII.—*continued.*

	Coralline Crag.	St. Erth Beds.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	
Lagena hexagona, *Will.*	..	×						
——— lævigata, *Reuss*	..	×						
——— lævis, *Mont.*	×	×						
——— lagenoides, *Will.*	..	×						
——— lineata, *Will.*	..	×						
——— lucida, *Will.*	..	×						
——— Lyellii, *Seg.*	..	×						
——— marginata, *W. & B.*	×	×						
——— melo, *D'Orb.*	×	×	×					
——— orbignyana, *Seg.*	..	×						
——— ornata, *Will.*	×	×						
——— quadrata, *Will.*	..	×						
——— ——— var. semialata		×						
——— seminiformis, *Schw.*	..	×						
——— semistriata, *D'Orb.*	×	×						
——— squamosa, *Mont.*	..	×	..	..	..	..	?	
——— striata, *D'Orb.*	×	×						
——— sulcata, *W. & J.*	×	×	×	..	×	..	?	
——— trigono-marginata, *P. & J.*	..	×						
——— trigono-oblonga, *Seg.*	..	×						
Marginulina glabra, *D'Orb.*	×							
——— raphanus, *D'Orb.*	×							
Miliolina agglutinans, *D'Orb.*	..	×						
——— bicornis, *W. & J.*	..	×						
——— Ferussacii, *D'Orb.*	..	×						
——— oblonga, *Mont.*	×	×	..	..	..	..	..	Triloculina.
——— pulchella, *D'Orb.*	×	..	..	..	..	..	?	Quinqueloculina.
——— sclerotica, *Karrer*	..	×						
——— secans, *D'Orb.*	..	×						
——— seminulum, *Linn.*	×	×	×	..	..	..	..	Quinqueloculina.
——— subrotunda, *Mont.*	×	×						
——— tenuis, *Czjzek*	×	..	..	..	..	..	..	Quinqueloculina.
——— triangularis, *D'Orb.*	×	..	..	..	..	..	..	Quinqueloculina.
——— tricarinata, *D'Orb.*	×	×	..	..	..	..	..	Triloculina.
——— trigonula, *Lam.*	..	×						
——— undosa, *Karrer*	..	×						
Nodosaria pyrula, *D'Orb.*	..	×						
——— raphanus, *Linn.*	×	..	..	..	×			

TABLE XIII.—*continued.*

	Coralline Crag.	St. Erth Beds.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.	
Nodosaria raphanistrum, *Linn.*	×							
——— scalaris, *Batsch*	×	×						
——— simplex, *Silv.*	..	×						
——— (Dentalina) brevis, *Reuss*	..	×						
——— ——— guttifera, *D'Orb.*	..	×						
Nonionina communis, *D'Orb.*	..	×						
——— depressula, *W. & J.*	..	×						
——— faba, *F. & M.*	×	..	×					
——— scapha, *F. & M.*	..	×	×					
——— stelligera, *D'Orb.*	..	×						
——— umbilicatula, *Mont.*	..	×						
Orbiculina adunca, *F. & M.*	×							
——— compressa, *D'Orb.*	×							
Orbitoides Faujasii, *Defr.*	×							
Orbitolites orbiculus, *Forsk.*	×							
Ovulites elongata, *Lam.*	×							
Patellina corrugata, *Will.*	..	×						
Planorbulina Haidingerii, *D'Orb.*	×							
——— mediterranensis, *D'Orb.*	×							
——— ungeriana, *D'Orb.*	×							
Polymorphina æqualis, *D'Orb.*	..	×						
——— amygdaloides, *Reuss*	..	×						
——— communis, *D'Orb.*	..	×						
——— complanata, *D'Orb.*	×	..	×					
——— compressa, *D'Orb.*	×	×	..	..	×	..	×	
——— gibba, *D'Orb.*	×	..	×					
——— gutta, *D'Orb.*	×							
——— hirsusta, *B., P. & J.*	..	×						
——— lactea, *W. & J.*	×	×	×	..	×	×	×	
——— oblonga, *Will.*	..	×						
——— problema, *D'Orb.*	×							
——— rugosa, *D'Orb.*	×							
——— Thouini, *D'Orb.*	×							
——— tubulosa, *D'Orb.*	×							
Polystomella arctica, *P. & J.*	..	..	..	..	..	..	×	
——— crispa, *Linn.*	×	×	×	×	×	×	×	
——— macella, *F. & M.*	×	×						
——— striato-punctata, *F. & M.*	×	×	×	×	×	×		
Pullenia sphæroides, *D'Orb.*	×	..	×					

TABLE XIII.—*continued.*

	Coralline Crag.	St. Erth Beds.	Walton Crag.	Red Crag.	Norwich Crag.	Chillesford Crag.	Weybourn Crag.
Pulvinulina auricula, *F. & M.*	×	×					
——— elegans, *D'Orb.*	×	×					
——— Karsteni, *Reuss*	..	..	..	..	×		
——— oblonga, *Will.*	..	×					
——— pulchella, *D'Orb.*	×						
——— repanda, *F. & M.*	×						
Quinqueloculina Brongniartii, *D'Orb.*	×						
——— Ferussacii, *D'Orb.*	×						
Rhabdogonium tricarinatum, *D'Orb.*	..	×					
Rotalia Beccarii, *Linn.*	×	×	×	×	×	×	×
——— calcar, *D'Orb.*	..	×					
——— dentata, *P. & J.*	..	×					
——— nitida, *Will.*	..	×					
——— orbicularis, *D'Orb.*	×						
——— punctato-granosa, *Seg.*	..	×					
Spirillina vivipara, *Ehr.*	×	×					
Spirolina cylindracea, *Lam.*	×						
Spiroloculina canaliculata, *D'Orb.*	×						
——— excavata, *D'Orb.*	..	×					
——— limbata, *D'Orb.*	..	×					
——— planulata, *Lam.*	×						
Textularia agglutinans, *D'Orb.*	×						
——— gibbosa, *D'Orb.*	×						
——— gramen, *D'Orb.*	..	×					
——— quadrilatera, *Schw.*	..	×					
——— saggitula, *Defr.*	×	×	×				
——— trochus, *D'Orb.*	×						
Truncatulina Haidingerii, *D'Orb.*	..	×					
——— lobatula, *W. & J.*	×	×	×	×	×	×	×
——— refulgens, *Mont.*	..	..	×				
——— tenuimargo, *Brady*	..	×					
——— ungeriana, *D'Orb.*	..	×					
——— variabilis, *D'Orb.*	..	×					
Uvigerina angulosa, *Will.*	..	×					
——— irregularis, *Brady*	..	..	×				
Vaginulina linearis, *Mont.*	×						
Verneuiliana communis, *D'Orb.*	×						
Virgulina schreibersiana, *Czjzek*	..	×					

Tunicates are represented in the Pliocene strata by a single species, probably *Leptoclinum tenue*, of which the spicules have been found at St. Erth by Messrs. Kendall and Bell. The only Pliocene hydrozoa are two species of *Hydractinia*, *H. circumvestiens*, S. Wood, and *H. pliocena*, Allm. The former is very abundant in the Coralline Crag, usually growing on *Trophon alveolatus*, but sometimes upon other gasteropods. Of sponges the only indications are the perforations made by *Cliona*, and some spicules belonging to the Calcisponges noticed by Dr. Hinde as occurring abundantly at St. Erth.

APPENDIX II.

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PLATE II.

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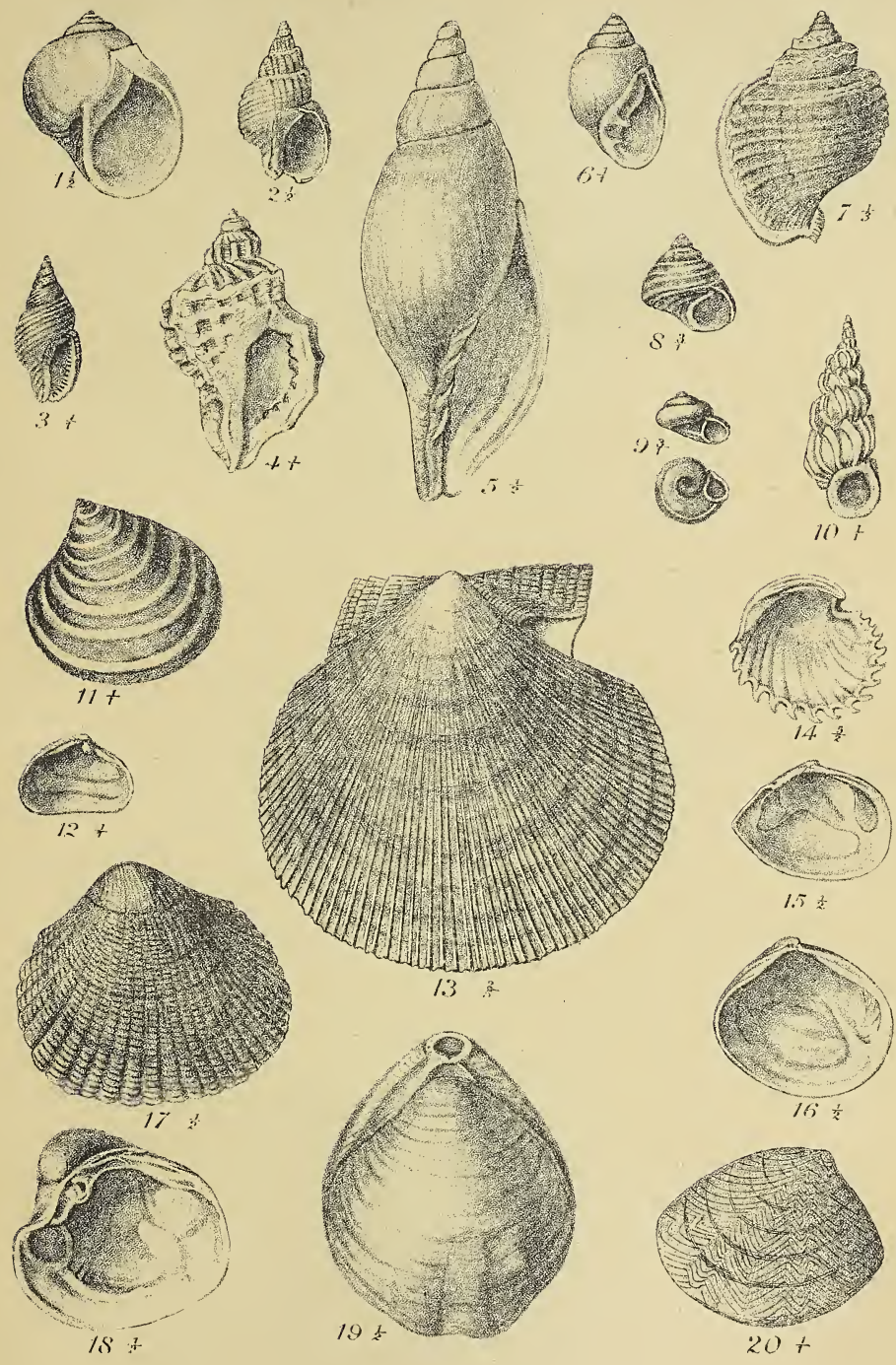
2. Nassa retusa, *J. Sow.*
3. Columbella sulcata, *J. Sow.*
4. Purpura tetragona, *J. Sow.*
5. Voluta Lamberti, *J. Sow.*
6. Melampus pyramidalis, *J. Sow.*
7. Cassidaria bicatenata, *J. Sow.*
8. Trochus obconicus, *S. Wood.*
9. Adeorbis supranitidus, *S. Wood.*
10. Scalaria foliacea, *J. Sow.*
11. Astarte Omalii, *Laj.*
12. Lepton deltoideum, *S. Wood.*
13. Pecten princeps, *J. Sow.*
14. Verticordia cardiiformis, *S. Wood.*
15. Tellina prætenuis, *Leathes.*
16. Tellina obliqua, *J. Sow.*
17. Cardium Parkinsoni, *J. Sow.*
18. Cyprina rustica, *J. Sow.*
19. Terebratula grandis, *Blum.*
20. Nucula Cobboldiæ, *J. Sow.*



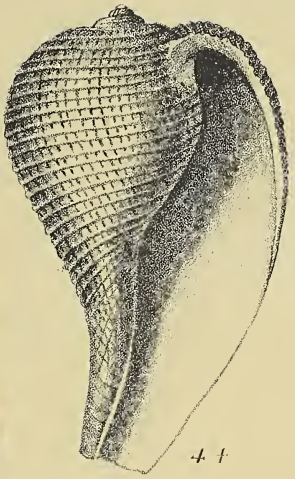
EXTINCT MARINE MOLLUSCA OF THE CRAG.

PLATE III.

1. Trochus Adansoni, *Payr.*
2. Erato Maugeriæ, *Gray.* (*a.* front. *b.* back.)
3. Turritella incrassata, *J. Sow.*
4. Pyrula (Ficula) reticulata, *Lam.*
5. Mitra ebenus, *Lam.*
6. Ringicula buccinea, *Broc.* (*a.* front. *b.* back.)
7. Ovula spelta, *Linn.*
8. Limopsis pygmæa, *Phil.*
9. Panopæa Faujasii, *Men. de la Groye.*
10. Cardita corbis, *Phil.* (*a.* outside. *b.* inside.)
11. Chama gryphoides, *Linn.*
12. Astarte incrassata, *Broc.*
13. Cytherea rudis, *Poli.*

1 ♀

3 ♀



4 ♀

5 ♀

a

2 ♀

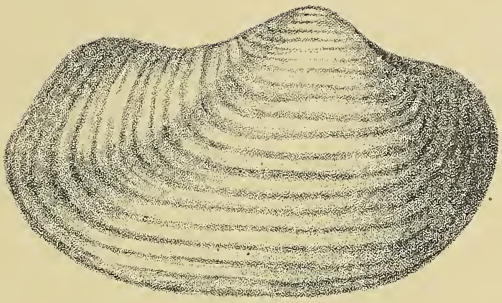
b

a

6 ♀

b

8 ♂



9 ♂

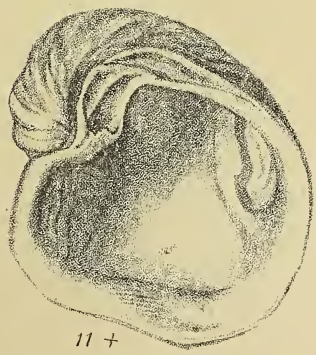
7 ♀

12 ♀

a

10 ♂♀

b



11 ♀

13 ♀

SOUTHERN MARINE MOLLUSCA OF THE CRAG.

PLATE IV.

1. Trophon scalariformis, *Gould.*
2. Natica islandica, *Gmel.*
3. Natica clausa, *Brod. & Sow.*
4. Cancellaria viridula, *Fab.*
5. Pleurotoma pyramidalis, *Ström.*
6. Velutina undata, *J. Smith.*
7. Scalaria grœnlandica, *Chemn.*
8. Tellina calcaria, *Chemn.* (= T. lata, *Gmel.*)
9. Cardium grœnlandicum, *Chemn.*
10. Astarte borealis, *Chemn.*
11. Astarte sulcata, *Da Costa.*
12. Astarte compressa, *Mont.*
13. Leda lanceolata, *J. Sow.* (*a.* inside. *b.* outside.)
14. Rhynchonella psittacea, *Chemn.* (*a.* side view of the exterior of both valves. *b.* interior.)

1 +

2 +

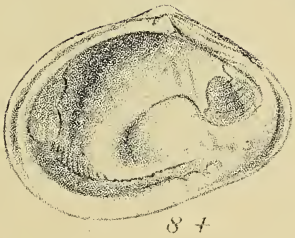
3 +

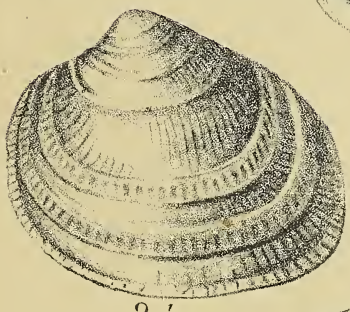
4 +

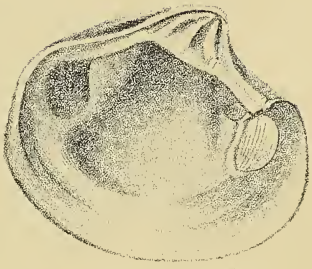
5 ½

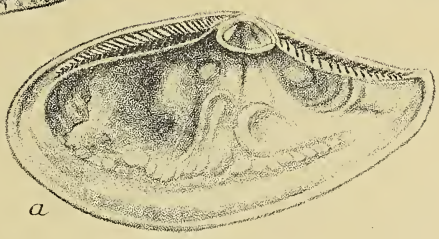
6 ½

7 +


8 +


9 +


10 +

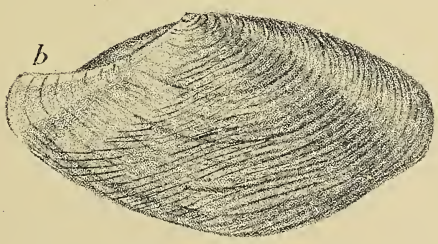

a

13 +

a

14 +

11 +


b

b

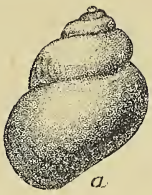
12 +

ARCTIC MARINE MOLLUSCA OF THE CRAG.

PLATE V.

1. Helix rysa, *S. Wood.*
2. Helix suttonensis, *S. Wood.*
3. Limax modioliformis, *Sandb.* (*a.* upper surface. *b.* lower surface.)
4. Paludina gibba, *Sandb.* (*a.* back. *b.* front.)
5. Paludina media, *Woodw.*
6. Paludina ? glacialis. *S. Wood.*
7. Valvata fluviatilis, *Colb.* (*a.* back. *b.* front.)
8. Hydrobia Steinii, *v. Martens.*
9. Lithoglyphus fuscus, *Pfr.* (*a.* side view. *b.* back.)
10. Nematuna runtoniana, *Sandb.* (*a.* back. *b.* front view of smaller specimen.)
11. Pisidium astartoides, *Sandb.* (*a.* inside. *b.* outside.)
12. Corbicula fluminalis, *Müll.* (*a.* inside. *b.* outside.)

1 ½



4 ½

2 ½

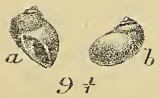
3 ½

5 ½

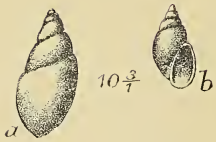
8 ½

7 ½

6 ½

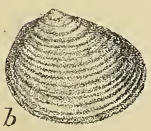


9 ½



11 ½

12 a ½



12 b ½

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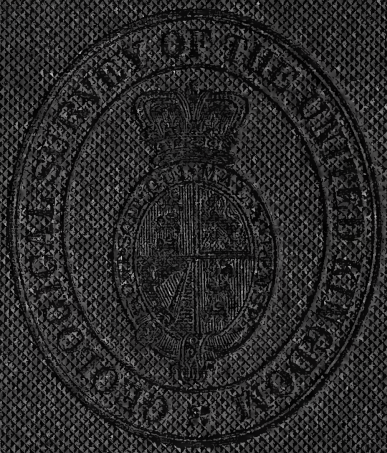
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